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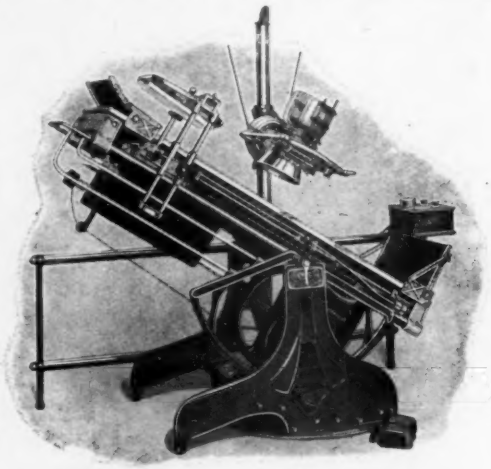

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THE AMERICAN JOURNAL OF ROENTGENOLOGY

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THE ABSORPTION OF RADIUM RADIATIONS BY TISSUES

By GIOACCHINO FAILLA, E. E.

Physicist to the Memorial Hospital

NEW YORK CITY

THIS investigation was undertaken for the purpose of determining the absorption by different tissues of the radiation of radium filtered through various thicknesses of metal. The scope of the work was to apply the knowledge thus obtained to radium therapy.

DESCRIPTION OF APPARATUS

The apparatus used for the experiments is shown in Figure 1. The conical ionization chamber is made of lead, and is supported vertically on a suitable frame not shown in the diagram. It is 51 cm. long, 3 cm. in diameter at the smaller end, and 12 cm. at the larger end. The wall thickness is 0.8 cm. A thin steel rod, tapered to a point, is suspended along the axis of the chamber, and is carefully insulated therefrom. The rod is electrically connected to the leaf post P of the electroscope by means of a fine copper wire which runs through brass tubes filled with paraffin. The electroscope is made of lead 1 cm. thick. The inside dimensions are 2.7 by 6 by 7 cm. It is arranged (as shown in the lower part of the figure) so that the gold leaf is projected on a ground glass screen. The lead cone, brass tubes, and electroscope case are all connected to the ground at G. The gold leaf of the electroscope is charged by pulling a string attached to a bell crank, so that the rod R, which is connected to a suitable source of potential, touches the leaf post. The wire in the ionization chamber will then be at the same potential as the leaf. The charging potential is adjusted so as to bring the image of the leaf always to the same point *a* on the screen. In taking readings, the observer sits in front of the ground-glass screen, and, with a stop watch, measures the time it takes the image of the leaf to travel between the points *b* and *c* on the screen.

The supports for the source of radiation, filter, and tissue, are made of hard rubber and very thin mica, as shown at AB. They are placed at such a distance from C that the source of radiation is practically at the apex of the cone. In this manner the beam of rays which enters the cone fills the whole chamber. The metallic filters are placed just above the radioactive source; the tissue is placed on the mica window B which is 1.5 cm. above the support for the filters. With this arrangement it is possible to change the filter without disturbing the tissue in any way. The lower end of the ionization chamber is closed by a very thin sheet of mica.

The radiation we wish to measure is only

the beam which enters the ionization chamber. It is necessary, therefore, to shield the electroscope itself from the radiation which the source emits in all directions. For this purpose a thick block of lead is interposed between the source and the electroscope, and the latter is so constructed that no stray radiation can enter it. The brass tubes are filled with paraffin for the same purpose of limiting the effect of the radiation to the air in the ionization chamber proper. The instrument was tested to see whether the shielding was sufficient, and it was found that the effect on the electroscope which was not due to the ionization chamber was negligible. Account had to be taken, however, of the "natural leak" of the instrument, that is, of the slow discharge of the electroscope leaf when the source of radiation which we wished to investigate was not present. This correction is made by subtracting the rate of fall of the leaf due to the natural leak alone from the rate of fall due to the combined effect of the radiation which enters the ionization chamber, and the natural leak.

It is important to bear in mind just what we are measuring with an apparatus of this sort, because on that depend the conclusions which we may draw from the experimental results. The cone of rays which enters the ionization chamber ionizes the air in it. The formation of ions implies that energy is being used up in the process, since work must be done to separate negative from positive electricity on account of the force of attraction between the two. This energy is supplied by the radiation. The difference of potential between the wire and the walls of the ionization chamber is sufficient to cause the positive and negative ions to be separated from each other as soon as they are formed, thus preventing their recombination. Under these conditions the electric current thus produced is proportional to the number of ions produced per second, which is a measure of the energy absorbed by the air in the chamber. The electroscope, used in conjunction with a stopwatch, measures this ionization current. Consequently the readings which we obtain in this manner are proportional to the energy absorbed.

The physiological action of radiation is dependent to a considerable extent on the amount of energy absorbed by the radiated tissue. It is evident, therefore, that ionization methods of measurement offer a good basis for the correlation of the physical factors of the dose of radiation administered and the physiological effects produced thereby. The method, however, has its limitations, which should be clearly recognized. In the first place, the medium in which the ionization is measured is a gas, and not tissue. When the constituents of the gas do not differ very much in atomic weight and relative proportions from the constituents of tissue, the absorption of radiation, mass per mass, is substantially the same. If we assume this to be true in the case of air, the thickness of tissue equivalent to the air in the ionization chamber of these experiments is about 0.6 mm. Secondly, the ionization of the air in the chamber consists of two parts, that produced directly by the passage of the beam of radiation through the air, and that produced by the scattered and secondary radiation excited by the rays which impinge on the walls of the chamber. When a metal ionization chamber is used, as in this case, the second term may be very important, according to the character of the radiation. Thirdly, the scattered and secondary radiations, which contribute to the effect in a deep-seated tumor, for instance, are quite different from their counterparts in the ionization chamber. These are the main physical differences between the conditions obtaining in laboratory experiments and in the treatment of patients. It is evident, however, that there are greater differences which are independent of physical conditions, but which are due to the inherent peculiarities of living matter. The physiological action of radiation depends not only on what takes place in the radiated tissue, but also on the reaction of the whole system. Naturally we cannot simulate this in *physical* experiments. Hence, in order to make practical application of the

results obtained from physical experiments, it is necessary to conduct physiological experiments complementary to the former.

EXPERIMENTAL PROCEDURE

To determine the absorption of radiation by tissue it was necessary to have uniform parallel slices of tissue about 5 cm. square. The thicker slices were cut by hand, using a knife with a wide blade. The thin slices were cut by means of a meat-slicing machine with a specially ground knife, after the tissue had been frozen hard. Tissue hardened in formalin could be cut with this machine without trouble. The thickness of the slices of tissue was determined by placing each between two thin sheets of lead and measuring the total thickness with a micrometer caliper. When the thickness of tissue on the mica support was several centimeters, the total thickness was checked by placing a steel scale against the pile of tissue. This procedure was especially necessary in the case of a very soft tissue, because its weight flattened the bottom layers. The density of the tissue was determined as follows: The tissue, in one or several pieces, was weighed with an accurate balance. Its volume was then determined by measuring the amount of water which it displaced, and the density obtained by dividing the mass by the volume. The weight of the tissue used for this determination was in every case several hundred grams. For the metals and solid bone the volume was calculated from the dimensions of a rectangular slab of the material.

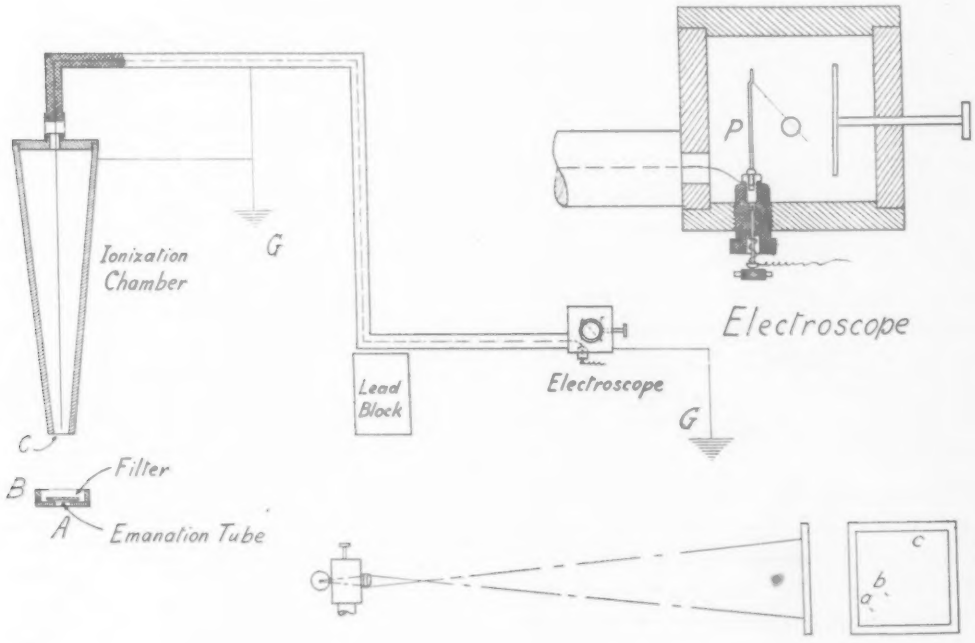

FIG. 1. *Projection of Gold Leaf on Ground Glass Screen*

The source of radiation used for these experiments was radium emanation enclosed in capillary glass tubes about 0.5 mm. in outside diameter and 14 mm. long. While the wall thickness of these tubes is sufficiently great (about 0.1 to 0.15 mm.) to absorb the alpha rays, it has little effect on the beta and gamma radiations. If such a tube, containing a suitable amount of emanation, is placed at A in the apparatus of Figure 1, the radiation will go through the very thin mica sheets at

B and C and will enter the ionization chamber without appreciable absorption. There it will ionize the air, and the electroscope will measure the ionization thus produced. Let us arbitrarily call the intensity of ionization in this case 100 units. If we place a slice of tissue 1 mm. thick on B, the radiation which enters the ionization chamber is only that part of the original beam which succeeded in getting through 1 mm. of tissue. This produces an ionization of 43 units in the chamber as measured by the electroscope. The addition of another millimeter of tissue (a total thickness of 2 mm.) reduces the ionization to 27 units. Continuing in this manner, for larger thicknesses of tissue, we obtain values of the intensity of ionization for different thicknesses of tissue interposed between the source of radiation and the ionization chamber. The results are shown graphically by curve A in Figures 3 and 4. A similar procedure using a metal or a metallic filter and tissue enables us to obtain the absorption curves shown in Figures 2, 3, and 4.

DISCUSSION OF ABSORPTION CURVES

In these experiments the ionization produced by the total radiation, beta and gamma, emitted by an emanation tube, was assumed to be 100 units. All other readings, therefore, represent percentages of the total radiation. As the range of values to be incorporated in the absorption chart is large, it was thought best to use a logarithmic scale. In this way, as the values decrease the scale is automatically increased. Furthermore, a logarithmic scale has the important advantage that it enables us to tell at a glance when the radiation becomes "homogeneous," because in this case the absorption curve is a straight line. For our purposes the radiation is homogeneous when successive equal layers of tissue absorb the same percentage of the radiation which reaches them. This means that the quality of the radiation remains substantially the same as it goes through the filter or tissue.

In Figure 2 are shown the absorption curves for different metals. It will be seen that the curves for metals of medium or low atomic weight become straight lines beyond a thickness of metal of a few millimeters. The curve for lead, on the other hand, does not become straight in the range of thickness shown in the chart. The mathematical law of absorption which applies to the straight part of the curve is

$$I = I_0 e^{-\mu d}$$

where I_0 = intensity of radiation falling on filter,
I = intensity of radiation passing through the filter,
d = thickness of filter,
e = Naperian base of logarithms,
μ = the coefficient of absorption.

The coefficient of absorption represents the fraction of the incident radiation which is absorbed or scattered per unit thickness of filter.* For the same quality of radiation, this is different for different absorbers, and for the same absorber it is different for different qualities of radiation. In the case of aluminum, for instance, the value obtained from the curve of Figure 2 is 0.11, and therefore 11% of the gamma radiation is absorbed per centimeter of aluminum. (The value given by Soddy and Russel[1] is 0.111, and by Rutherford and Richardson[2] is 0.115.) In the case of brass the value of μ for gamma rays is 0.35, so that brass absorbs $\frac{0.35}{0.11} = 3.2$ times more gamma radiation per unit thickness than aluminum. The thickness of lead used in these experiments (2 cm.) was not sufficient to give a straight line in the absorption curve. Hence it is not strictly correct to speak of a coefficient of absorption for this curve. However, if we make the calculation for the last part of the curve we find that μ equals 0.58, which is somewhat higher than the value of 0.5 given by Rutherford.[3] This shows that the hard-

* In thinking of the coefficient of absorption in these terms, care should be exercised to choose a unit of thickness which will make the amount of radiation absorbed by a filter of unit thickness a small fraction of the incident radiation.

ness of the gamma radiation from radium increases with the thickness of filter beyond 2 cm. of lead. In fact, from the experiments of Tuomikoski[4] and others, it appears that the penetration of the gamma radiation of radium increases even after filtration by several centimeters of lead. Such excessive filtration, however, is entirely out of the question in radium therapy, on account of the weight of the filter and the diminution of the quantity of radiation which passes through it. Even for 20 mm. of lead the ionization produced by the transmitted radiation is only 1.5% of the value for the unfiltered beta and gamma radiation, and less than ¼ the value for radiation through 1 mm. of lead.

Fortunately no such filtration is necessary in therapy. In the first place, the fact that the aluminum and brass curves become straight lines beyond a thickness of a few milllimeters indicates that radium radiation filtered through 6 mm. of aluminum or 2 mm. of brass is sufficiently homogeneous to be absorbed by these metals according to the exponential law given above, within the range of thicknesses shown in Figure 2.

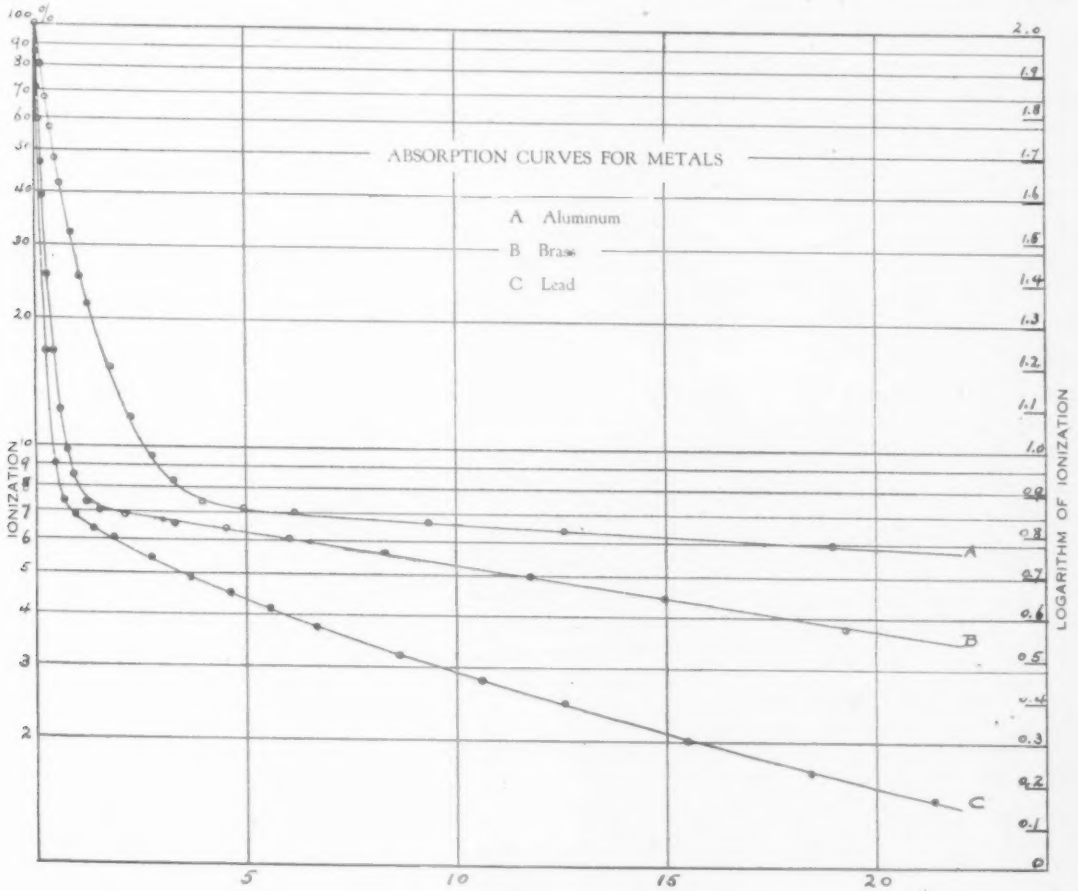

FIGURE 2.

The reason is that for substances of low atomic weight the coefficients of absorption as here defined do not vary much with the wave length, for gamma radiation of the quality considered.[5] *A fortiori* this is true of the absorption of tissue, the principal constituents of which are much lighter than these metals. In the case of lead, the mechanism of absorption is further complicated by the fact that the element is an isotope of Radium B.[6]

In Figures 3 and 4 are shown the curves of absorption by tissue of the radiation filtered through different thicknesses of brass and lead respectively. The circles indicate the points which were experimentally determined. The largest thickness of tissue used in these experiments was about 7 cm. For this reason the prolongation of the curves to 10 cm. is shown in dotted lines. We are justified in extrapolating to 10 cm. because many other curves we have obtained in the course of our work, using up to 9 or 10 cm. of tissue, have been straight lines, within the limits of experimental error. In either chart the highest curve is for the total radiation, beta and gamma, emitted by the small capillary glass tube containing radium emanation. It will be seen that there is a sharp bend in the curve corresponding to a thickness of about 1 cm. of tissue. This is the point at which a transition occurs in the quality of the radiation, from a preponderance of beta and soft gamma rays to a preponderance of hard gamma rays. The presence of soft radiation is evident, however, even up to thicknesses of tissue of 5 or 6 cm.

The lowest curve, F, in either set represents the absorption of radiation by the metal filter alone. These curves are the same as shown in Figure 2, but plotted to a different scale. The absorption curves for filtered radiation branch out from these curves. The filters used were approximately ½, 1, 2, and 3 mm. of either brass or lead. For any point on the curve the thickness of tissue is added to the thickness of filter. Thus for the third curve, C, in Figure 3, we have: a brass filter 0.96 mm. thick reduces the ionization from 100 to 7.6%, the further addition of 1 cm. of tissue brings the ionization to 6.2%, and so on. The curves are plotted in this manner so that each is a complete absorption curve, starting with unfiltered radiation.

For deep therapy it is essential to use radiation which is absorbed exponentially by tissue; that is, radiation which is absorbed to the same extent by successive layers of tissue. If this is not the case, the skin and superficial layers will absorb a larger percentage of the incident radiation than corresponding layers of tumor tissue, and therefore will be affected more strongly, even if it were possible to use a parallel beam of radiation. As the dose is adjusted so as not to injure the skin, it follows that by using a filter which does not give a homogeneous radiation, the tumor does not receive as much radiation in proportion as it would if sufficient filtration were used. Thus, if the filter consists of ½ mm. of brass, from Figure 3 we see that the first centimeter absorbs $\frac{14.5 - 6.4}{14.5} = 56\%$ of the incident radiation, the second centimeter absorbs 9%, but the third and each subsequent centimeter absorbs only 7.7%. On the other hand, using 2 mm. of brass as a filter, the first centimeter absorbs 10%, the second, third, etc., 7.5%, and the difference, which in this case is due to the secondary radiation of brass,[7] is small. The further addition of a secondary filter of 2 or 3 mm. of rubber, which has about the same absorbing power as tissue, makes the percentage absorbed by the first and successive centimeters of tissue the same.

The criterion for the exponential absorption of radiation is that the absorption curve, when plotted to a logarithmic scale, be a straight line. From Figures 3 and 4, therefore, we can determine what filtration to use to fulfill this condition. Evidently there is more than one choice. However, not all possible combinations of primary and secondary filter which could be used are equally economical. In the first place, it will be seen that in no case is the absorption curve a straight line when the ionization is over 6%. This means that at best we can use for deep therapy only 6% of the radiation emitted by the bare glass tube. At this point it is interesting to note that when tissue is used as the absorber, the absorption is not exponential up to a thickness of about 5 cm. Accordingly if tissue or some organic substance of about the same density were used for deep therapy, a thickness of five or more centimeters would be necessary. Aside from the inconvenience

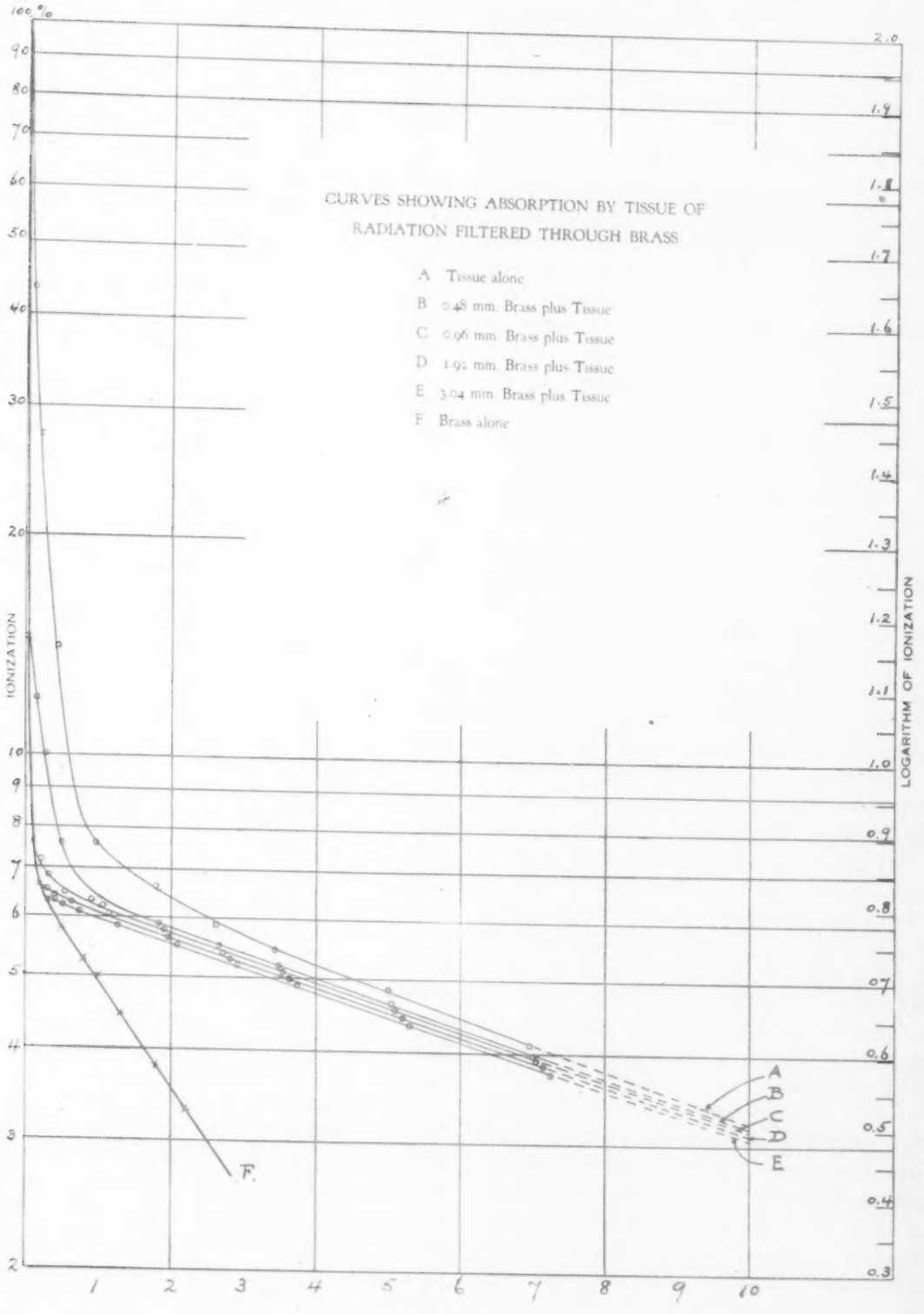
CURVES SHOWING ABSORPTION BY TISSUE OF
RADIATION FILTERED THROUGH BRASS
A Tissue alone
B 0.48 mm. Brass plus Tissue
C 0.96 mm. Brass plus Tissue
D 1.92 mm. Brass plus Tissue
E 3.04 mm. Brass plus Tissue
F Brass alone
IONIZATION
LOGARITHM OF IONIZATION
100 %
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
1
2
3
4
5
6
7
8
9
10
A
B
C
D
E
F

FIGURE 3.

of such a bulky filter, its use would entail an unnecessary loss of radiation, because the ionization produced by radiation filtered through 5 cm. of tissue is 4.8%, while other filters can give 6%. The reason for this is that the diminution of the intensity of the beam of radiation passing through a filter of low atomic weight is primarily due to the scattering of the radiation and not to true absorption. Since the scattering by substances of low atomic weight is not very different for the different qualities of radiation, the softer components of the beam of radiation are not effectively eliminated in this manner. Hence substances of low atomic weight are not efficient filters,[8] and the large thickness required to obtain the proper filtration causes undue scattering and absorption of the penetrating radiation as well. This brings out the desirability of using a metalic filter. In general an additional filter of low atomic weight is necessary to remove the soft, secondary radiation of the metal.[7]

The straight line parts of the curves of Figures 3 and 4 are not parallel, but nearly so. This means that filtration by different thicknesses of the same metal changes the penetrating power of the radiation somewhat. The magnitude of this change can be seen from Table II, in the column for the percentage of radiation absorbed by 1 cm. of tissue. Thus, when the filter is ½ mm. of brass, 1 cm. of tissue absorbs 7.7%, while for 3 mm. of lead filtration the corresponding value is 7.1%. The radiation in the latter case is more penetrating than the former. If we increase the filtration considerably, the penetrating power of the radiation can be increased further.

In deep therapy there are two factors which affect the amount of radiation which reaches the tumor: the distance of the tumor from the source of radiation and the absorption of part of the radiation by the intervening layers of tissue. For any one set of conditions, that is, distance of source from skin, strength and distribution of source, and depth of tumor, the quantity of radiation which reaches the tumor depends on the penetrating power of the radiation. The more penetrating the radiation, the more of it will reach the tumor. From this point of view, therefore, it is obvious that it is desirable to use the most penetrating radiation available. This, however, is not the only consideration involved in the problem. When radium is used as the source of radiation, the only means of obtaining a more penetrating radiation is the use of a heavier filter, which of necessity entails a decrease in the amount of the available radiation. Furthermore, the limiting factor in deep therapy is the effect on the skin, since this is always greater than in deep layers, neglecting any difference in susceptibility which may exist between different tissues. Therefore it is important to know what fraction of the radiation which falls on the skin reaches the tumor. The maximum value of this fraction is determined by the relative distances of the skin and tumor from the source. Thus, if a point source of radiation is placed at a distance of 3 cm. from the skin, and the farthest point of the tumor is 3 cm. below the skin, (i.e., 6 cm. from the source) the most that the tumor can receive is ¼ as much as the skin. This is on the assumption, which can never be realized in practice, that the 3 cm. of tissue intervening between the source and the back of the tumor do not absorb any radiation at all. Allowing for the absorption by the tissue of radiation filtered through 1 mm. of brass plus 8 mm. of rubber, we find that the distant parts of the tumor receive 19.9% of the radiation which falls on the skin, instead of 25%. Using a filter of 3 mm. of lead plus 7 mm. of rubber, the radiation at the back of the tumor will increase from 19.9% to 20.2%; that is, it will be 1.5% greater for the same skin dose. This, however, will decrease the intensity of the source of radiation from 6.3% to 4.6%, or 27%, so that in order to obtain the same skin dose using the same amount of radium the duration of the application must be prolonged 27%. The advantage of getting 1.5% more radiation in the tumor may offset the disadvantage of a longer exposure, but, is there any other

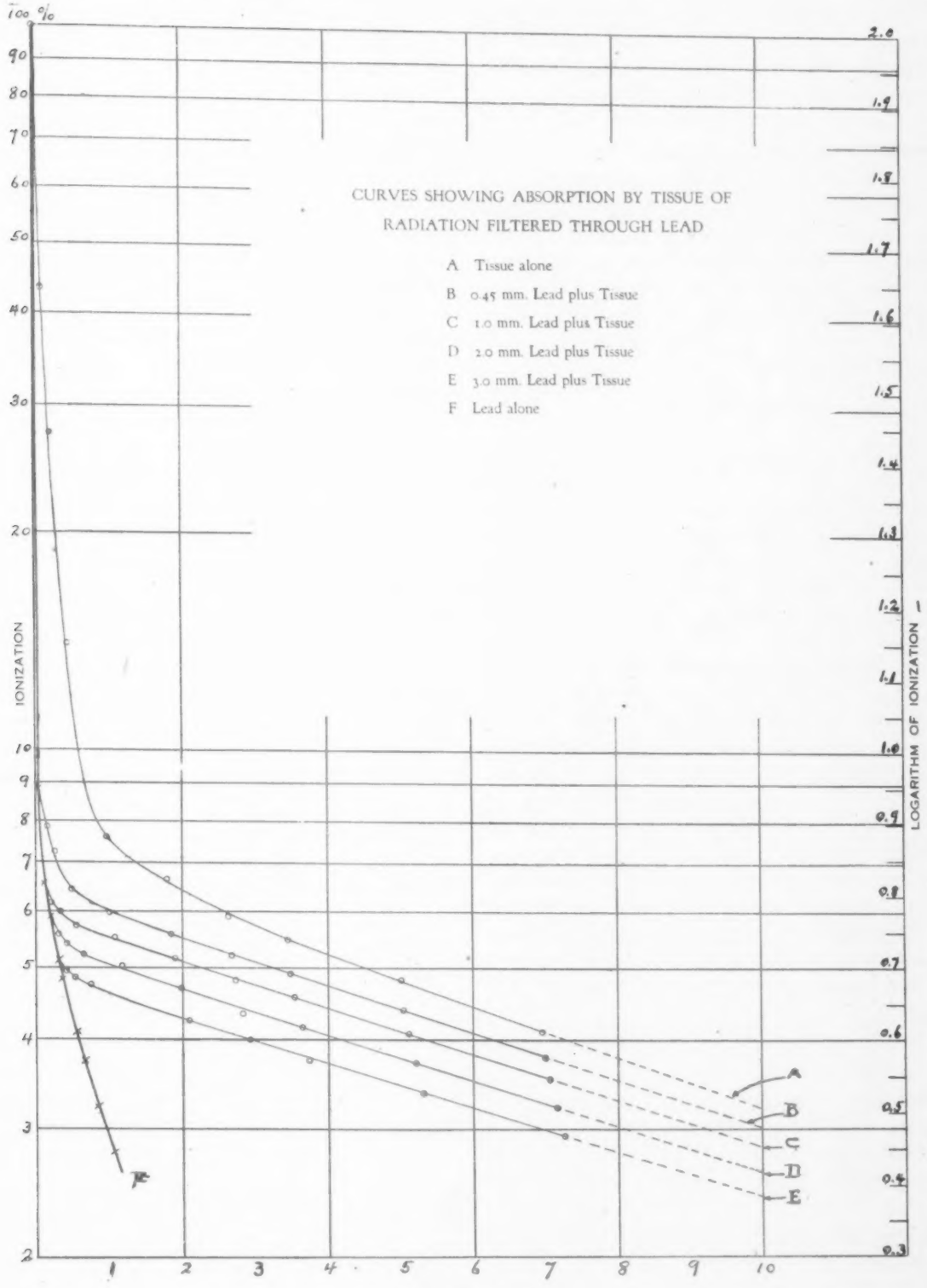
CURVES SHOWING ABSORPTION BY TISSUE OF
RADIATION FILTERED THROUGH LEAD
A Tissue alone
B 0.45 mm. Lead plus Tissue
C 1.0 mm. Lead plus Tissue
D 2.0 mm. Lead plus Tissue
E 3.0 mm. Lead plus Tissue
F Lead alone
IONIZATION
LOGARITHM OF IONIZATION
100 %
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
2
3
4
5
6
7
8
9
10
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
A
B
C
D
E
F

FIGURE 4.

way of accomplishing the same purpose with greater economy? The relative amount of radiation which reaches the tumor can be increased also by placing the radium at a greater distance from the skin while still using the same filtration as in the first case. Let us determine what this distance should be in order to have 1.5% more radiation in the tumor, that is, 20.2% of the amount reaching the skin. Figure 5 shows the notation used below. The percentage of the skin radiation which reaches the tumor is given by the expression $\frac{100\,x^2}{(x+z)^2} \times e^{-\mu d}$. If this is to be 20.2% when $z = 3$, $\mu = 0.0755$, then $\frac{100\,x^2}{(x+3)^2} \times 0.797 = 20.2$, whence $x = 3.1$ cm. Therefore in this particular case an increase of 0.1 cm. in the distance of the applicator is sufficient to increase the tumor radiation 1.5%. To get the same skin dose the time will now have to be increased in the ratio $\frac{(3.1)^2}{3^2} = 1.068$, or less than 7%. Since in using a higher filtration we found that the time of application had to be increased 27%, it is evident that the same result can be obtained more economically by increasing the distance. This example has been worked out to illustrate this point. In practice, however, an increase of 1.5% would be insignificant. If we had considered the dose at a much greater depth, the effect of a higher filtration would have been larger, and the adjustment in distance to get the same result would have been necessary.

From the law of conservation of energy it follows that, in order to affect the tissue, some of the radiant energy traversing the tissue must be absorbed by it. In fact, as stated in the first part of the paper, there is considerable evidence tending to show that the physiological effect is dependent on the amount of radiation absorbed by the tissue. From this point of view, then, there is an advantage in using radiation which is more easily absorbed by tissue, provided we can obtain the same ratio between the skin dose and the tumor dose, by properly adjusting the distance of the applicator. This simply means that for the same total amount of radiation falling on the skin a given physiological effect can be obtained in a shorter time in the case of the softer radiation. As, however, the time element does not influence the ratio between the skin dose and the deep dose, it will be seen that the fact that tissue absorbs more of the softer radiation does not tend to increase the deep dose in comparison to the skin dose. On the contrary, it is very effective in decreasing the amount of radiation which reaches the deeper layers of tissue.*

In the light of what has just been said, it is reasonable to ask: Can we obtain the same relative dose of radiation at a certain depth of tissue by using *x*-rays and placing the tube at a greater distance from the skin? The answer to this question depends entirely on the quality of the *x*-radiation available. In the example given above it will be seen that the controlling element was the "dispersion" of the radiation and not the absorption. Considering the effect of distance alone, the dose at a depth of 3 cm. was only 25% of the dose on the skin, that is, there was a loss of 75%. On the other hand, the loss due to absorption by 3 cm. of tissue was 20.3%, which is small in comparison. In the case of *x*-rays the conditions are reversed. The target-skin distance probably would not be less than 20 cm. Then for a tissue depth of 3 cm. the dose, neglecting absorption, would be $\frac{(20)^2}{(23)^2}$ or 75.7% of the skin dose. To get the same percentage of the radiation as in the previous case, that is 20%, we can now afford to lose 55.7% through absorption. Using the same equation as before we can

*In working out the above example no account was taken of the above mentioned effect of the quality of the radiation on the time of irradiation. This is justified because the quality of the radiation in the two cases was only slightly different, and under these conditions the ionization method of obtaining the absorption curves used in solving the problem automatically compensates for the difference in the absorption of the two types of radiation.

determine the degree of penetration which the x-rays must have in order to get at a depth of 3 cm., 20% of the radiation falling on the skin.

$x = 20$, $z = 3$. $\frac{100 \times 20^2}{(20+3)^2} e^{-3\mu} = 20$. Therefore $\mu = 0.443$. That is, when a homogeneous x-radiation is $\frac{0.443}{0.0775} = 5.87$ times less penetrating than the gamma rays, and the target is at a distance of 20 cm. from the skin, we get at a depth of 3 cm. of tissue 20% of the radiation falling on the skin. If, however, for the purpose of comparison, we place our radium source at a distance of 20 cm. then the dose at a depth of 3 cm. is 60% of the skin dose instead of 20%.* In practice it is desirable to have as little difference as possible between the skin dose and the tumor dose. This condition would obtain if the source were placed at a great distance from the skin; that is, for parallel rays. Then the only factor which limits the radiation at any depth is the absorption. If parallel radiation were used, we would get at a depth of 3 cm. 79.7% of a skin dose in the case of gamma rays, and 26.4% in the case of x-rays six times less penetrating than gamma rays.†

Table I gives the relative amounts of radiation reaching different tissue depths for different conditions of application.

A comparison of columns F, B, and D shows that when the distance of application is increased from 3 cm. to 20 cm., the radiation at a depth of 3 cm. increases from

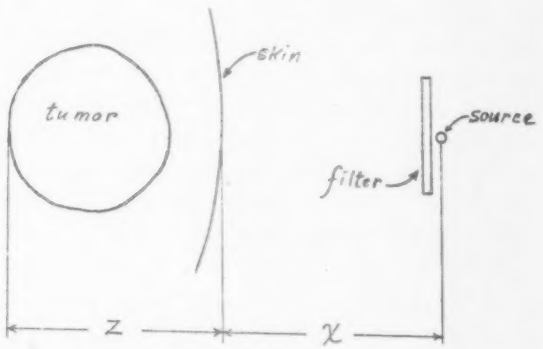

FIG. 5. Diagram showing relative positions of tumor, skin and source of radiation.

19.9% to 60.2%, while the theoretical maximum for infinite distance is 79.7%. From this we see that when the distance of application is great in comparison to the tissue depth, further increase in the distance is of little help in increasing the tumor dose. The values in columns F and G show that when the distances are adjusted so as to get the same skin dose and the same tumor dose at a depth of 3 cm., using radiation of different degrees of hardness, the doses are not the same at any other tissue depth, and especially at greater depths than the one for which the

TABLE I

A	B	C	D	E	F	G
Tissue depth cm.	*Source 20 cm. from skin*		*Source at infinite distance*		*Ra. 3 cm. from skin*	*Target 20 cm. from skin*
z	Gamma rays $\mu = 0.0755$	*X*-rays $\mu = 0.443$	Gamma rays $\mu = 0.0755$	*X*-rays $\mu = 0.443$	Gamma rays $\mu = 0.0755$	*X*-rays $\mu = 0.443$
0	100	100	100	100	100	100
1	84.2	58.4	92.8	64.3	52.2	58.4
2	71.0	34.0	85.9	41.1	31.0	34.0
3	60.2	20.0	79.7	26.4	19.9	20.0
4	51.2	11.8	73.9	17.0	13.6	11.8
5	43.8	7.0	68.5	10.9	9.6	7.0
7	32.3	2.5	58.9	4.5	5.3	2.5

* Whence we see the advantage of using a more penetrating radiation when the conditions of application are the same.

† The filtered x-radiation used at the present time for deep therapy is about twice as penetrating as the x-rays of this example, and less than one third as penetrating as the gamma radiation of radium when the filter is 2 mm. of brass.

doses are the same (3 cm.). The more penetrating radiation "wins out." This may be an advantage or a disadvantage according to the conditions.*

There are some limitations to the applicability of the results so far obtained which should be mentioned at this point. The most important is the effect of the scattered and secondary radiation on the tumor dose. The amount of radiation which reaches the tumor may be divided into two parts (1) that which travels in a straight line from the source to the tumor, and (2) that which reaches the tumor in a roundabout way. The latter is composed of (a) the radiation which is scattered, that is, deflected from its straight line path by the tissue surrounding the tumor, and (b) the secondary radiation which is set up in the tumor by the primary beam. The relative amounts of (1) and (2) depend on the depth of the tumor, the latter becoming more important as the depth increases. The method of measurement adopted for these experiments enables us to measure only the amount of the primary radiation which reaches a certain depth of tissue. The data thus obtained, therefore, enable us to calculate the *minimum* amount of radiation which reaches a given tumor under the conditions of application. The upper limit is obtained by neglecting the absorption of radiation by tissue and calculating the effect of distance alone. The actual radiation which reaches a certain depth of tissue is between these two limits. It can be determined by using a different experimental arrangement, which we hope to do in the near future.

Another limitation is imposed by the use of a metallic ionization chamber, as discussed in the first part of the paper. This, however, influences our results only when the quality of the radiation whose absorption we are measuring is changed appreciably in passing through the tissue used as the absorber. As this does not occur in the case of the penetrating radiation used in deep therapy, no error is introduced in using, for this purpose, the data here obtained. But it is not possible to use these absorption curves to determine accurately the beta ray dose for the skin from a knowledge of the gamma ray dose, or vice versa. For instance, if the ionization value of the bare emanation tube is 100%, and for a tube screened by 2 mm. of brass it is 6.7% (Figure 3, curve D), it is not correct to assume that, other conditions being the same, the time of exposure to produce the same superficial effect in the case of the screened tube would be $\frac{100}{6.7}$ or 15 times longer than in the case of the bare tube. The two have to be determined independently by physiological experimentation. The curves enable us to make a first approximation to the doses for various qualities of radiation; the correct values can be obtained by actual trial.

There is another point which requires further elucidation, that is, the significance of the ionization values given in the charts. A given quantity of radium emits radiation in all directions. The amount of radiant energy which passes through a surface of unit area perpendicular to the line of propagation represents the intensity of the radiation at this surface, independently of the quality of the radiation under consideration. But if we attempted to measure this intensity using ordinary ionization methods, the value we would obtain would depend to a great extent on the quality of the radiation. For instance, for beta rays, we could have an ionization chamber in which the gas would absorb all the radiation entering it, but for gamma rays only a fraction of the total radiation would be absorbed. In the latter case, then, we would not be measuring

* From the preceding discussion we see that, within certain limits, we can get the same amount of radiation at a given depth of tissue for the same skin dose by using radiation of distinctly different penetrating power, provided the distance of application is suitably chosen. Whether we would get the same physiological effect is a different matter, and one which cannot be determined by physical experiments alone. The question really is whether the physiological effect is independent of the quality of the radiation. At the present time this is not definitely known, but the scanty evidence available in the literature seems to support the conclusion that within certain limits it is independent of the quality.

the intensity of the radiation. To take the extreme case, if there were radiation which would not be absorbed at all by matter, then, however strong the source might be, we would never detect it by the means at our disposal, or, in fact, by any other means, if the law of conservation of energy is to hold. For this reason, when we are dealing with radiation of different qualities, and especially of different types, as the beta and gamma rays, we cannot speak of their relative intensities. Therefore the values on the charts are given in percentages of the total ionization produced when the emanation tube has no additional filtration, and they do not represent the intensity of radiation after passing through a filter or tissue or both, but the intensity of ionization which it produces. Accordingly it is not strictly correct to say that the radiation of an emanation tube is decreased from 100% to 6% by a filter of 2 mm. of brass plus 10 mm. of tissue. The radiation, considering the energy which is associated with it, is more than 6%, but this figure indicates the availability of its energy in affecting matter. For our purposes this is not a disadvantage, but an advantage. We are not concerned with the amount of radiation passing through tissue, but with the amount which is capable of influencing vital processes. When the quality of the radiation is not materially changed by the absorber, it is correct to say that the intensity of the radiation is decreased a certain percentage by the absorber. In such cases the factor of proportionality between the energy of the radiation and the amount absorbed remains the same. In addition to the effect of the material of the ionization chamber on the percentage values given for the different thicknesses of absorber, it should be borne in mind that the numerical values depend on the quality of the radiation which is taken as producing 100% ionization. This in turn depends on the wall thickness of the glass tube containing the emanation, which, however, does not affect the relative position of the curves.

In Table II, column 5, are given the coefficients of absorption for different metals and different tissues. Little need be added to what has already been said about the absorption by metals. The three coefficients given for lead indicate the change in the quality of the gamma radiation as the thickness of lead increases. In column 4 are shown the range of thicknesses for which the coefficients of absorption were determined. Column 6 shows the half value thickness, that is, the thickness of absorbing material needed to reduce the radiation to one half its initial value. The density (column 7) and the coefficient of absorption divided by the density (the so-called mass absorption coefficient, column 8) are given to show how the absorption varies with the density of the absorber. In column 9 are found the percentages of the radiation absorbed per millimeter of filter corresponding to the absorption coefficients given.

The values in the second part of the table were determined from the curves of Figures 3 and 4. They show the relative change in the absorption of radiation filtered through various thicknesses of lead and brass by beef muscle hardened in 10% formalin. It will be seen that from a filter of ½ mm. of brass to one of 3 mm. of lead the change is $\frac{0.0765 - 0.0709}{0.0765} = 7.3\%$. The mass absorption coefficients have no special significance in this case, and they are not included in the table. It should be noted that the values in column 9 are given for one centimeter of tissue, and not for one millimeter, as in the case of metals.

The values in the third part of the table indicate the relative absorption of the radiation filtered through 1.92 mm. of brass by different tissues. For these experiments fresh organs were obtained. They were cut into as nearly parallel slices as possible, and absorption curves similar to those of Figures 3 and 4 were determined. The experimental work for fresh liver, spleen, muscle, brain, suet, and lung, as well as the formalined muscle, was done continuously, with the same emanation tube in the same position from

beginning to end. To make sure that the experimental conditions remained the same throughout, the absorption curve for pure gum rubber was determined at intervals, and used as a check. This also enabled us to include in the table some data obtained on previous occasions. The logarithms of the ionization values for different thicknesses of tissue were plotted to a very large scale and average straight lines drawn, as in the case of Figures 3 and 4. The coefficients of absorption were then determined by reading off two values from the straight lines.

From column 9 we see that the amount of radiation filtered through 1.92 mm. of brass which is absorbed by one centimeter of tissue is not very different for the different kinds of tissue. The two conspicuous exceptions are solid bone, which absorbs almost twice as much radiation as the average, and lung, which absorbs a little more than half as much as the average.

It is often assumed that the absorption of gamma rays is proportional to the density of the absorber. The table enables us to test the accuracy of this assumption. If the absorption were proportional to the density, then all the values in column 8 for the same quality of radiation would be the same. Evidently this is not the case. From physical experiments we know that the mass absorption coefficient (μ/ρ) is the same for substances which have essentially the same chemical composition. As this condition is practically fulfilled by all the soft tissues given in the table, we should expect the values of μ/ρ to be substantially the same. If we stop to analyze the results we find that, within the limits of experimental error this is the case. For lung tissue the value of μ/ρ is considerably lower than the average. The discrepancy, however, can be attributed to the numerous air spaces in this kind of tissue, which are included in the measurement of thickness, but are not included in the determination of the density, since they do not contribute to the volume of the piece of tissue measured by the amount of water displaced. The calculated density, consquently, was too high, and the mass absorption coefficient too low. The smaller difference in the value of μ/ρ for brain may be accounted for in the same way.

The explanation of the low value of μ/ρ for solid bone is based on the results of many physical experiments, which show that the mass absorption coefficient is lower for substances of medium atomic weight than for substances of very low or very high atomic weights.[9] Thus in Table II it is seen that the value for soft tissues, which have essentially the same composition and contain only elements of low atomic weight, are higher than for aluminum or brass, but lower than the first value for lead, which has a very high atomic weight. (The other values for lead are not comparable with the tissue values because the quality of the radiation in the two cases is quite different.) Solid bone, which contains considerable calcium, therefore, approaches aluminum in absorbing power, and for this reason the value of μ/ρ is lower than for soft tissues. "Porous bone," as used in this experiment, consisted of a bony structure having its interstices filled with soft tissue. Theoretically, then, the value of μ/ρ should be higher than for solid bone and lower than for soft tissue. Experimentally it is found that this is the case.

Considering the methods of determining the density of soft tissues, it is reasonable to conclude that, within the limits of experimental error, the mass absorption coefficients for soft tissues are equal. For practical purposes, therefore, we may say that in this case the absorption of gamma rays filtered by 1.92 mm. of brass is proportional to the density of the tissue. This is not the case when tissue is compared with aluminum and brass. For instance, if we know the coefficient of absorption for aluminum and we calculate its value for tissue of density 1.03, in the ratio of the densities, we get $\mu = 0.11 \times \frac{1.03}{2.74} = 0.0413$. But the value experimentally determined is 0.0694, which is 68% higher than the calculated value. On the other hand, the absorption of gamma rays by

tissue when calculated from the absorption by pure gum rubber, is correct for practical purposes. ($0.066 \times \frac{1.03}{.97} = 0.070$ instead of 0.069.) In the case of solid bone the absorption per centimeter is greater than for aluminum, in spite of the fact that the density of the latter (1.74) is considerably greater than the density of bone (2.01). In radiotherapy it is often assumed that the absorbing power of one centimeter of tissue is the same as that of one millimeter of aluminum. Probably this is true for x-rays of a certain quality, but it is very far from the truth in the case of gamma rays.

With the exception of solid bone the tissue which absorbs most radiation absorbs 7.5% per centimeter of thickness. Therefore, if in calculating the amount of radiation which reaches a certain depth, we take the value of

TABLE II

1 *Filter*	2 *Thickness mm.*	3 *Absorber*	4 *Range mm.*	5 *Coef. of Abs. cm.*$^{-1}$	6 H. V. T.* *cm.*	7 *Density*	8 μ/ρ *cm.*$^{-1}$	9 *% abs. per mm.*
Aluminum	6	Aluminum	6-22	0.11	6.3	2.74	0.0402	1.1
Brass	2	Brass	2-22	0.35	1.98	8.26	0.0424	3.5
Lead	2	Lead	2-5	1.01	0.686	11.34	0.0892	10.1
Lead	5	Lead	5-10	0.80	0.866	11.34	0.0705	8.0
Lead	10	Lead	10-15	0.66	1.05	11.34	0.0582	6.6
Lead	15	Lead	15-22	0.58	1.20	11.34	0.0511	5.8
								% abs. per cm.
Tissue	5.00	Formalin Beef Muscle	50-60	0.0815	8.50			8.2
Brass	0.48	Formalin Beef Muscle	10-70	0.0765	9.06			7.7
Brass	0.96	Formalin Beef Muscle	10-70	0.0755	9.18			7.6
Brass	1.92	Formalin Beef Muscle	10-70	0.0752	9.22	1.056	0.0713	7.5
Brass	3.04	Formalin Beef Muscle	10-70	0.0752	9.22			7.5
Lead	0.45	Formalin Beef Muscle	10-70	0.0752	9.22			7.5
Lead	1.0	Formalin Beef Muscle	10-70	0.0736	9.42			7.4
Lead	2.0	Formalin Beef Muscle	10-70	0.0726	9.54			7.3
Lead	3.0	Formalin Beef Muscle	10-70	0.0709	9.77			7.1
Brass	1.92	Solid Bone	3-20	0.13	5.5	2.01	0.063	13.
Brass	1.92	Porous Bone	20-100	0.075	9.3	1.15	0.065	7.5
Brass	1.92	Liver	20-90	0.074	9.4	1.06	0.070	7.4
Brass	1.92	Spleen	20-100	0.073	9.5	1.05	0.070	7.3
Brass	1.92	Muscle	20-100	0.069	10.0	1.03	0.067	6.9
Brass	1.92	Brain	20-100	0.066	10.6	1.03	0.064	6.6
Brass	1.92	Suet	20-100	0.065	10.7	0.94	0.069	6.5
Brass	1.92	Lung	20-70	0.045	15.5	0.78	0.057	4.5
Brass	1.92	Rubber	10-50	0.066	10.5	0.97	0.068	6.6
Brass	1.92	Formalin Beef	20-70	0.075	9.2	1.06	0.071	7.5

*Half Value Thickness

0.075 for the absorption coefficient, we are sure to be on the safe side. It will be seen also for deep radium therapy that the effect of intervening bones on the tumor dose must be small, because the actual thickness of solid bone is small in comparison to the thickness of soft tissues, and the absorption by porous bone is only slightly greater than that of soft tissues. This, however, is not true in the case of x-rays, and especially of soft x-rays. A convincing proof of this statement is afforded by x-ray photographs taken with soft and very hard rays. As for the absorption by human tissue compared to beef tissue, it may be said that in general the former absorbs a little less radiation than the latter. The difference, however, is practically negligible when the same kind of tissue or organ is considered in the two cases. One notable exception is fat, the absorption by human fat being considerably less than the absorption by suet. But in this case the densities are also quite different. The absorption by the fat under the human skin is about two thirds that of an equal layer of the skin proper.

SUMMARY

1. The apparatus used, consisting of a gold leaf electroscope and conical ionization chamber, and the experimental procedure are described in detail.

2. The most important limitations imposed by the experimental method adopted are discussed. They are due to:

(a) Use of a metal ionization chamber.
(b) Use of a gas as the absorbing medium in the ionization chamber.
(c) Exclusion of scattered and secondary radiation produced in tissue.
(d) Inability to reproduce in the physical laboratory physiological conditions.

3. The absorption curves for aluminum, brass, and lead are given. From these we see that:

(a) As the filter increases the transition from soft to hard radiation is quite sharp.
(b) Beyond a thickness of filter of a few millimeters in the case of aluminium and brass the absorption is exponential ($I = I_0 e^{-\mu d}$). In the case of lead it is not exponential in the range of thickness used.
(c) This shows that the filtration by a small thickness of metal is sufficient to give a radiation which is absorbed exponentially by metals of medium or low atomic weight. The radiation, however, is not strictly homogeneous, as indicated by the lead absorption curve.

4. The criterion for the quality of radiation to be used in deep therapy being the exponential absorption of the radiation by tissue, from Figures 3 and 4 we see that:

(a) A metal should be used as the primary filter.
(b) A secondary filter, composed of light elements like tissue, should be used to remove the soft, secondary radiation of the metal.
(c) There are different combinations of primary and secondary filters suitable for deep therapy.
(d) Beyond a certain point additional filtration, while increasing the penetrating power of the radiation slightly, decreases the intensity of the radiation considerably.

5. In deep therapy the limiting factor is the effect on the skin. Therefore it is important to know what fraction of the skin radiation reaches a given depth of tissue. The value of this fraction can be varied within limits by varying the distance of the applicator from the skin, or the filtration.

(a) An example is worked out to show that in the case of gamma rays it is more economical to increase the percentage of the skin radiation which reaches a deep tumor by increasing the distance of the applicator than by increasing the filtration.

(b) A second example shows that, using two sources of radiation of distinctly different penetrating power, we can get the same percentage of a skin dose at a certain depth of tissue in either case by choosing the distance of application properly.

(c) Table I shows that when the distance of the applicator is large in comparison to the tumor depth, the penerating power of the radiation has the greater influence on the tumor dose. (This is the case of *x*-rays.) On the other hand, when the distance of application is about the same as the tumor depth, and the radiation is very penetrating, the distance has the greater influence on the tumor dose. (This is the case of radium therapy.)

(d) The table shows, also, that when the distances are adjusted so as to get the same skin dose and the same dose at a depth of three centimeters, using radiation of different degrees of hardness, the doses are not the same at any other tissue depth, and especially at greater depths than the one for which the doses are the same.

6. The coefficient of absorption is the important factor which identifies radiation. The numerical value depends on the quality of the radiation and on the nature of the absorber. From Table II we see that:

(a) When the same tissue is used as an absorber and the filtration of radium rays is varied in steps from 0.48 mm. of brass to 3 mm. of lead, the coefficient of absorption gradually decreases from 0.0765 to 0.0709. But while the penetrating power of the radiation is increased 7.3% by the additional filtration, the available radiation is decreased 65%.

(b) The same radiation (1.92 mm. brass filter) is absorbed to a different extent by different tissues. For soft tissues the coefficient of absorption is proportional to the density of the tissue.

(c) The absorption by tissue from different organs (except lung tissue, fat, and solid bone) is nearly the same. Therefore if we take 0.075 for the value of the coefficient of absorption of gamma radiation filtered through 1.92 mm. of brass, we are sure to be on the safe side in any calculation we may make for practical use. Corresponding to this value of the absorption coefficient, the thickness of tissue necessary to absorb one half of the radiation is 9¼ centimeters. As a round figure, easy to remember, we may take the half value thickness of human muscle tissue for gamma rays to be ten centimeters.

(d) The presence of bone in the path of the radiation is of no great consequence in regard to the amount of gamma radiation which reaches the tumor beyond it. The only part of the bone which absorbs considerably more than muscle is the solid part. But in any practical case this makes up a small fraction of the total thickness traversed by the radiation. In the case of *x*-rays bone plays a more important part.

7. The results obtained from the experiments described in this paper can be used for the solution of problems in radium therapy, subject to the following limitations:

(a) The calculated amount of radiation reaching any given tissue depth is always the *minimum* amount which will reach this depth under the conditions of application.

(b) Skin doses of beta and gamma radiation are not to be compared according to the ionization values given in Figures 3 and 4. They must be determined independently by physiological experiments.

In conclusion the author wishes to acknowledge his indebtedness to Mrs. E. H. Quimby for her assistance in the preparation of the material for this paper.

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PERSONAL EXPERIENCE WITH THE APPLICATION OF THE NEWER ROENTGEN THERAPY IN CANCER*

By M. J. SITTENFIELD, M.D.

NEW YORK CITY

THE ideal that every therapy attempts to attain is a complete inhibition and neutralization of the disease, and if possible the maintenance of normal function. Unfortunately excision of a cancer does not prevent further invasion, nor immunize against it, nor does it maintain the functions of the tissue affected. So it is easily conceivable why radiotherapy, even with our former limited knowledge, played such an important part in the treatment of cancer. The fact that recent advances in the technique of radiotherapy have been accomplished abroad makes it apparent that the older methods were found wanting. It is almost needless to say that insufficient penetration of hard rays to the deeper tissues was one of the shortcomings; another was the lack of measurements for practical purposes, and also the lack of knowledge of the exact dosage necessary to influence a carcinoma, a sarcoma or ovary.

Some of these obstacles were overcome by the construction of more powerful apparatus, and also tubes to tolerate higher intensities. The electroscope and iontoquantimeter furnished means of measurement for practical purposes, and with these, the determination of dosage for the destruction of carcinoma and sarcoma were made possible. Apparatus, tubes and technique have been described elsewhere, and need not be mentioned here.

The application of the newer methods of roentgen therapy has led to more gratifying results in the treatment of cancer. Since my return from abroad in the middle of September, owing to the delay in shipping the German apparatus, this improved technique as far as it is applicable to my own apparatus, has been made use of. The following case report is, of course, a preliminary one, and only one of a type has been selected.

One of the first cases selected for this newer therapy was a patient with an inoperable carcinoma of the cervix. She had received a radium treatment three and a half months previous, with no evident arrest of the disease. The malignant process continued, so that when she first came to me, her hemoglobin was 40 per cent, and to all appearances, she was in a beginning state of cachexia. Desirous of trying out the newer technique, she was subjected to the following treatment: a two hour radiation dose on four consecutive days was administered, instead of one session of eight hours, as in Bumm's Clinic. The focal distance used was 50 cm., and the portals of entry 15 by 18 cm. The rays were filtered through 0.5 mm. of zinc, plus 1 mm. of aluminum. In addition 50 mg. of radium element were introduced into the cervix and left there for fifty hours. My aim was to administer what the Germans call a full cancer dose at one session. The reaction was not as severe as those I

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saw in Germany when the entire treatment was given in one day. The patient gained five pounds in weight within the first week, pain disappeared entirely, and she is at present going about, engaged in her usual activities, free from any clinical manifestations of the disease. A month ago examination of the cervix showed it to be entirely fibrosed.

Another patient was referred for radiation for recurrent carcinoma in the axilla after radical excision of a carcinoma of the breast. Female, sixty years old, was operated upon for carcinoma of the breast a year and a half ago. Six months later a tumor recurred in the axilla; it was removed again, only to recur within the year. The recurrence, when she reported to me, was the size of half an orange, it was a fluctuating mass of broken-down, necrotic tissue. She suffered much pain, and had to be constantly under the influence of opiates. All in all, she was in pretty bad shape. She also received four radiation doses of two hours each on consecutive days. A dose was directed from front of axilla, one posteriorly into axilla, one from above the shoulder joint, and one from below into the axilla. The focal distance was 50 cm., the filter zinc plus aluminum, and the portals of entry 15 by 18 cm. Four days after completion of the roentgen treatment, 3,000 mg. hours of radium element were placed in the axilla over four areas. A week later the tumor had disappeared entirely, she was free from discomfort, and had left off all narcotics.

In another patient a carcinoma of the breast had recurred over the anterior region of the sternum. The patient was operated upon two and a half years ago for carcinoma of the breast at Mt. Sinai Hospital, had a stormy convalescence, developed erysipelas with abscesses, and had to stay in the hospital for three months. In October last a recurrence of about 12 by 15 cm., the size of the palm of my hand, developed over the sternum extending to the anterior axillary border. Two radiation doses of four hours each, with 70 cm. focal distances, portals of entry 15 by 18 cm., zinc and aluminum filters, were administered. A week later the tumor had receded by half, and in another week the entire tumefaction had disappeared. In this case, about seven weeks ago, a tumor the size of a large lemon made its appearance in the other breast. The surgeon again referred her for radiation, considering her a bad risk for surgical intervention. A full cancer radiation dose was administered, and the tumor has since receded.

These reports are of course only preliminary; the end results may be such, perhaps, as to cause a modification. Furthermore the response in all cases may not be as striking as in these. It is obvious, however, that more intensive radiation than heretofore must be administered along the lines of modern technique. The dosage in this newer technique comprises a more thorough understanding of the biological and physical properties of the rays as they are emitted from the tube, and of the accompanying secondary radiation. The quality of ray, in particular, is one of the most important factors, and of equal importance are the substance and amount of filtration used, the focal distance, and the size of the portals of entry. The proportionate relationship between the radiation energy at the surface of the body, and that of the lesion in the deeper tissues, is called the dosage quotient. This dosage will be most favorably effective in the deeper tissues when we increase the distance of the radiation source, notwithstanding the fact that an increase in the focal distance necessarily increases the time of obtaining a skin erythema dose.

It is well known that with 0.5 or 1 mm. of copper or zinc as a filter, a considerable amount of the energy emitted from the tube is lost. This loss is more than compensated for by the fact that radiation through 0.5 or 1 mm. of copper or zinc produces a more favorable absorption coefficient. In other words rays from this point on will show very little qualitative change, and additional filtration would serve no further purpose.

In addition to the primary rays, the scattered secondary rays materially aid the

dosage quotient. For instance, it has been worked out by Friedrich and others, that with 50 cm. focal distance, and a 10 mm. aluminum filter, the primary radiation energy under 6 cm. of tissue would be 22 per cent that of the surface dose; in reality, though, it is increased to 51 per cent by the scattered secondary rays.

CHART I

Filter	*Focal Distance*	*Depth under Surface*	*Estimated Primary Dosage %*	*Actual % with Secondary Rays*
10 mm. Alum.	50 cm.	6 cm.	22. %	51. %
"	50 cm.	8 cm.	13.8%	42. %
"	50 cm.	10 cm.	8.4%	31. %
1 mm. Copper	50 cm.	6 cm.	25. %	67.5%
"	50 cm.	8 cm.	17. %	54. %
"	50 cm.	10 cm.	10. %	44. %

Aside from this increase in the amount of radiation available in the deeper tissues through the proper filtration, the size of the portals of entry must be given consideration. For example, under 10 cm. of tissue, with a portal of entry of 1.5 by 2 cm., the dose is 9 per cent of that received on the surface; with a portal of 6 by 8 cm., however, the amount is increased to 28 per cent, and with portals of 10 by 15 cm., to 35 per cent, and so on. In other words, the larger the portal of entry, the more favorable is the dosage quotient, up to a point of 20 by 20 cm. Any increase in size over this seems to bring no appreciable gain; that is, the intensity of the ray diminishes by dispersion the smaller the portal of entry, and increases in percentage the larger the portal of entry.

CHART II

DOSAGE QUOTIENT IN THE DEEPER TISSUE
(Focal Distance 50 cm.)

Portal of Entry	*Under 10 cm. Tissue*	*Under 3 cm. Tissue*
1.5 x 2 cm.	9%	47%
6 x 8 cm.	28%	66%
10 x 15 cm.	35%	77%

Chaoul, of Sauerbruch's Clinic in Munich, has adopted a very ingenious device of wax blocks, which he calls a "ray concentrator." One set is arranged on either side of the tube, and another at each side of the radiated field, taking in the entire distance between the skin and the tube. In this way he collects or concentrates the rays of dispersion which are then deflected to the center of the field, and thus increases the radiation quotient from 40 to 60 per cent. It becomes essential therefore in order to reach the tumor with the most favorable and suitable dosage quotient, to increase the focal distance, to use filtration of at least 0.5 mm. of copper or zinc, and lastly to use as large a portal of entry as the conditions permit.

Opitz of Freiburg has taken advantage of all these factors which increase the dosage quotient, in the treatment of carcinoma of the uterus, first, by using a focal distance of 50 cm., and second, by enlarging the portal to its maximum of 20 by 20 cm., and by using 1 mm. of copper as a filter. In this manner a skin erythema dose requires about two hours, one application is administered from the abdomen, one from the back, and two from the side. Here also a minor detail of refinement is made use of: the anterior dose is administered so that the centralized ray strikes the left edge of the tumor slightly obliquely, and the posterior dose the right edge of the tumor, in order to prevent damage to the rectum, which is anatomically situated to the left. The sum total of the rays reaching the cancer mass in this manner is very nearly a full cancer dose. To guard against a sublethal dose to the interior of the tumor, a small dose of radium is placed in the uterus. Even if the cancer itself receives slightly more than a knockout dose, the healthy adjacent tissue tolerates this and thus escapes damage.

CHART III

DOSAGE QUOTIENT UNDER THREE CM. OF TISSUE

Portal of Entry	*Focal Distance*	%
9 x 12 cm.	30 cm.	74%
10 x 15 cm.	50 cm.	86%
9 x 12 cm.	50 cm.	86%
15 x 15 cm.	80 cm.	90%
9 x 12 cm.	100 cm.	90%
10 x 15 cm.	100 cm.	93%

That intensive radiation for short periods is much more effective than smaller doses for longer periods is pretty generally conceded, and practical use is made of these pathological and biological findings. It holds true also, with small doses frequently repeated, that the period of latency is considerably protracted, and furthermore a cumulative effect may be experienced producing chronic changes which are not at all desirable, either by stimulating the growth itself, or by damaging the healthy tissue. Great stress is laid upon the advisability of administering the entire lethal dose at one sitting. There are, however, times when the entire dose cannot be administered in one day. The condition of the patient or the danger of absorption toxemia may not admit of this. At any rate all efforts should be directed to administering a full lethal dose within a week.

By way of summary I would like to draw special attention to the following points:

It is most essential that sufficient intensive roentgen or radium rays be administered to knock out completely all parts of the cancer without damaging or destroying adjacent healthy tissue. If any one part of the tumor receives a sublethal dose, failure and recurrence is sure to follow.

To effect the most favorable conditions of radiation to the deeper tissues, proper filtration, increase in the focal distance, and increase in the size of the portals of entry must be made use of.

The determination of correct dosage comprises knowledge of the clinical location of the tumor, its pathology, radiation dosage quotient, and absorption coefficient.

From the personal application of this technique in this short period of time, I gain the impression that raying in the form of a complete knockout dose administered at one time will bring about better results in cancer therapy.

CLINICAL RESULTS FROM THE NEWER TECHNIQUE OF DEEP ROENTGENTHERAPY IN MALIGNANT DISEASES

By GEORGE E. PFAHLER, M.D.

PHILADELPHIA, PENNSYLVANIA

DURING September, 1920, Drs. Coolidge and Schmitz brought back to us from Germany the information that in Germany a greater amount of filtration was being used in the treatment of deep-seated malignant disease, with the source of rays at a greater distance from the skin and with the use of a higher voltage. The impression of the few men who had the privilege of visiting the German clinics was that more satisfactory results were obtained from this technique than from the lighter technique used in this country. Our equipment in America did not permit an exact duplication of the technique used in Germany because our apparatus as built to-day will not generate current at a voltage greater than 125,000, or at most 130,000. It seemed important, therefore, to see whether the technique could be improved with our present apparatus and then perhaps later to determine whether the results obtained by such improvement would correspond to the results obtained in Germany. It is always desirable to proceed from the known to the unknown, and instead of jumping wildly from one technique into another of unknown quantity and unknown value, I proceeded by calculations to transform my former technique for deep roentgentherapy into my present technique. Generally my former technique consisted of 5 milliamperes of current at 126,000 volts, at a focal skin distance of 20 cm. filtered through 6 millimeters of aluminum, for a period of 8 minutes. My present technique consists of the use of 5 milliamperes at 126,000 volts, filtered through 10 millimeters of aluminum or glass, at a focal skin distance of 30 cm., for a period of forty to fifty minutes. I find that forty minutes will rarely give an erythema, and that fifty minutes will generally give an erythema. This technique has been developed gradually, in part by calculations and in part by experimentation.

I would like to add a caution at the beginning of this article and repeat it again at the end: it is most important in every instance before the current is turned on that the filters be counted to make sure they are in place, because if filtration is deficient this prolonged treatment will produce an incurable burn. As a precaution against an accident I require that two people make observations on the filters for every dose given. If the equipment is arranged for deep treatment only, so that this one uniform technique is used continually for all kinds of cases, then the filters can be permanently put in place and the precaution of counting will not be necessary, but in the general roentgenological laboratory the apparatus must be used for different purposes and 10 millimeters of filter is not always desirable, because it wastes energy unnecessarily.

RELATIVE VALUE OF FILTERS

In order that our technique be made understandable it is necessary to know the relative value of various filters. Several years ago, at one of these midwinter meetings of this Society, I recommended the use of glass instead of aluminum because the metal filters frequently led to puncture of the Coolidge tubes. From a scale furnished by the Radium Chemical Company of Pittsburgh, I observed that glass had approximately the same filter value as aluminum. Therefore by using glass we obtained a filter less likely to lead

*Read at the Midwinter Meeting of the Eastern Section of THE AMERICAN ROENTGEN RAY SOCIETY, Atlantic City, N. J., January 28, 29, 1921.

to punctures of the tubes and that serves equally well for filters. For this purpose the ordinary glass used for photographic negatives was cut to the proper size. First of all we made a direct comparison of many layers of this glass and in our own laboratory found it to be uniform. I am told by Professor Shearer that glass is not uniform in its density, and therefore I caution others against the use of glass until it has been compared carefully with aluminum or some other standard, after which I believe that it can be used safely. For this purpose we took 10 millimeters of aluminum and 10 millimeters of glass and with the current such as is used for treatment above described we were able to prove that, at least so far as the photographic values are concerned, the two are equal. The exposures were made of ⅛, ¼, ½, ¾ and 1 second. In order to form some idea of the relative value of filters such as are used in Germany I then made a comparison photographically of copper and aluminum. In Germany, as you will recall, they are using from ½ to 1 millimeter of copper as a filter. By my experiments I learn that ½ millimeter of copper is equal to 13 millimeters of aluminum measured photographically.

With the above technique and with exposures lasting from forty to fifty minutes (and in a few cases I have given sixty minutes), it is self-evident that it is undesirable from every standpoint to limit our field of radiation to small areas such as we have been doing in the past. I think most of us have gradually increased the size of the field of exposure. When we consider that the smaller the field of radiation, the less the amount of secondary radiation, and since we must acknowledge that the secondary radiation probably does as much as the primary radiation towards destroying malignant disease, and in fact may be the sole cause of destruction of the malignant cells, the relative value of small areas and much cross-firing decreases. It is always desirable to cross-fire as much as possible providing we are actually cross-firing, but mere division of the surface of the body into small areas, as I have often seen done, does not actually increase the cross-fire value. For example, in the treatment of carcinoma of the uterus, it is my practice to treat the local disease directly by radium and then to cross-fire through an area extending from the symphysis pubis to the umbilicus and to the anterior superior spines on each side, and either use this as one area for treatment or divide it into two. Then a similar dose is given through each lateral surface of the pelvis and one or two similar areas posteriorly. In this way all parts of the pelvis are irradiated and I have seen some most brilliant results. For example, a patient referred to me on September 30, 1920, by Dr. Wm. R. Nicholson, was considered by him totally inoperable. The entire cervix, including the walls of the upper part of the vagina, were involved by the carcinoma, making a total area of malignant disease 7 or 8 cm. in diameter. She received 4200 milligram hours of radium treatment locally and two courses of *x*-ray treatment consisting of four areas in each course during six weeks. At the end of two and a half months all evidence of disease had disappeared. Even in recurrent disease about the pelvis, with the above technique I have obtained results that I have never seen equalled by my former technique. In recurrent and metastatic disease of the breast and in primary disease of the breast I have seen results which are far superior to those obtained by my former technique. In a few primary cases that for some reason were considered inoperable, I have seen all palpable evidence of malignant disease of the breast including recurrent and metastatic nodules, disappear more rapidly and more satisfactorily than formerly. I have also seen recurrent nodules disappear that gave no response to the technique formerly used.

I think all of us have made the observation in the treatment of malignant disease that unless a pronounced primary effect is obtained and the disease made to disappear within a few months, it often develops a resistance which is as great as that of the

surrounding tissues, and therefore it requires an amount of treatment necessary to destroy the malignant disease such as will also destroy the surrounding healthy tissue. I believe, therefore, that it is desirable in all instances to get as much treatment into the malignant disease within the first month or two as can be borne by the healthy tissues, and in this way the malignant disease is destroyed while it is yet more sensitive to radiation than the healthy tissue. For this reason I dislike treating a patient who has been inefficiently treated for several months and then referred to me because the disease has made progress.

Another phase of this newer deep roentgen therapy that cannot be ignored refers to the radiation sickness. Those who give small and frequent doses are less concerned about the radiation sickness. There is, however, nothing magical in anyone's technique with regard to radiation sickness. It is probably a measure of the amount of radiation and the reaction of the tissues and the nervous system therefrom. Those who give little radiation will therefore have little radiation sickness. We immediately found, therefore, that as we increased the length of our exposures we also increased the radiation sickness, both in frequency and degree. We are hoping, by careful study of the subject, to learn how to overcome this condition; but for the present an increase of the interval between the treatments or doses given has been found to be our best safeguard. One cannot, however, I believe, obtain the same results by too much division of dosage; and if we use this deeper technique and at the same time attempt to give it in fractional doses, the expense thereof will be correspondingly increased, and unless most carefully managed may allow the cancer cells to mature and develop a greater resistance to the rays. As it is, the expense of giving a dose of the deeper therapy is greatly increased as compared with the former technique. One must, therefore, keep the practical side in mind until more powerful equipment is developed and some means found of reducing the expense due not so much to apparatus, electricity, etc., as to human service.

With increase in the length of exposure one also encounters the increased danger of stray radiation and secondary radiation. Therefore greater precautions are necessary to guard against leaking tube shields, or any other form of stray radiation. As a step in this direction, I have designed the protecting device previously described.[1] If more powerful apparatus is developed we must also keep in mind that with increased power comes increased danger, which necessarily calls for increased precautions.

I believe the technique above described to be a definite advance. It will probably be further modified and further developed, but so far it is adaptable to our present outfits, and if used with great caution greater beneficial results can be obtained. I think we may draw the following conclusions at present:

1. Increased filtration, with increased focal skin distance, will increase the value of deep radiation as compared to the surface effect.

2. By increasing the above two factors the time of radiation is greatly increased—probably five-fold. This prolonged radiation in itself may be an important factor in preventing cell division and regeneration of the cancer cells.

3. Radiation sickness is increased, and extra effort must be made to overcome this effect.

4. The greatest caution must be observed in keeping the filters in place and at their full prescribed quantity.

5. Increased protection is necessary for both the patient and the operator.

6. The clinical results obtained from this new deeper technique excel those obtained formerly.

[1] A New Device for Increasing the Protection of Both the Patient and the Roentgenologist. Presented before the Philadelphia Roentgen Society January 13, 1921, and THE AMERICAN ROENTGEN RAY SOCIETY, Atlantic City, N. J., January 29, 1921.

A NEW DEVICE FOR INCREASING THE PROTECTION OF BOTH THE PATIENT AND THE ROENTGENOLOGIST*

By GEORGE E. PFAHLER, M.D.

PHILADELPHIA, PENNSYLVANIA

WITH the increase of power in our exciting apparatus there has been a progressive increase in dangers to both the patient and the roentgenologist. These dangers consist primarily of injuries from the high tension current to either patient or roentgenologist, and secondarily and more insidiously the dangers from stray radiation. With the death of one physician and two patients during the past two years from accidental contact with the high tension circuit it is incumbent upon us to utilize every means possible to eliminate such possibilities; and while the device which is here described briefly and illustrated more particularly may not give absolute security, it surely does give increased protection. It is important to see, of course, that there are no loose wires or any that are likely to become loose; but there still remains the possibility that during an examination a patient may bring some part of his body within sparking distance of the high tension current, and we know that when the arc once starts through the air, which ordinarily is an insulator, but which then becomes a conductor, a large amount of current can easily flow into the patient, and the results above referred to indicate the danger.

The danger from stray radiation to both the patient and the operator has increased with the increased voltage and filtration. While these stray rays are never as strong as those applied directly to the part being treated, as we increase the time of exposure (which increases with the amount of filtration), any escape of stray rays through the opening in the glass shields becomes a serious danger to both patient and roentgenologist; and while the roentgenologist is farther away than the patient, he is exposed to these stray rays over so much longer period of time that they become a danger to him. For instance, most of us who are now using 5 milliamperes of current and 9 inch parallel spark gap, can give an erythema dose of unfiltered rays in approximately one minute at a distance of 8 inches. With increased filtration to 10 millimeters of aluminum and increased distance to 12 inches the time is increased to as much as fifty minutes and therefore, even though only one-tenth or one-hundredth as much radiation comes through the opening in the glass bowl as is passed through the opening in the diaphragm, it becomes a serious danger to both the patient and the operator.

As a step towards overcoming these dangers above described, I have made use of opaque rubber which contains approximately 25 per cent of lead and which has an insulating value equivalent to a 4 inch spark. That is, it will force a spark to leap around the edge for a distance of 12 inches before puncturing the rubber. But since the distance from the terminal of the tube to the top of the rubber is only 8 inches the actual insulation value is only about 4 inches, because the current tends to creep along the rubber to about one half the air spark resistance. The rubber is about 3 millimeters thick, and is sold as Hercules red rubber packing. A piece of this rubber, 12 inches by 18 inches, is attached to the base of the diaphragm and is then curved over the ends

*Read at the Philadelphia Roentgen Society, January 13, 1921, and at the Midwinter Meeting of the Eastern Section of The American Roentgen Ray Society, Atlantic City, N. J., January 28, 29, 1921.

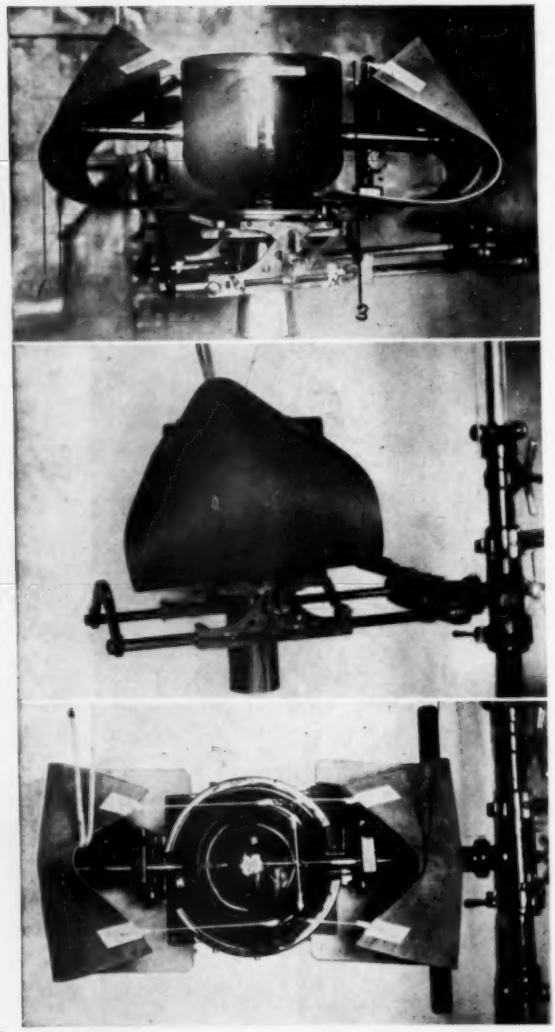

FIG. A (*above*). LATERAL VIEW, showing the opaque lead rubber curved about the ends of the tube and closing off the line of radiation through the openings in the tube. (1) The opaque rubber. (2) Reinforcement layer. (3) Springs and hooks holding the top of the lead rubber together across the top of the lead glass shield.

FIG. B (*middle*). Front view of protective shield.

FIG. C (*below*). Top view of protective shield.

of the tubes and the wires, and is folded back towards the glass bowl so as to cover both the front and the back and at the same time to carry the wires upward 8 inches. The central portion of this rubber directly in front of the terminals of the tube is reinforced by another thickness of this rubber, 6 inches by 6 inches, which increases the insulation and increases the protection against the roentgen ray. The upper ends of this rubber are fastened together by cords and small hooks so that they can be easily released when it is necessary to change the tube. The changing of tubes is fortunately not so frequent as was necessary with the old type of gas tube, and therefore the inconvenience of making these connections is of secondary importance. This rubber protection can be adapted to any type of tube holder. At least, we have adapted it to six different types used in our laboratory and while I am only illustrating one, a little ingenuity on the part of the roentgenologist or a mechanic will enable him to adapt the device to anyone's use. The photographs have been made in three different views and I think illustrate the attachment and application better than I can do by description. On one tube stand we have found an advantage in extending the cords over a cross-piece resting on two posts which fit over the rim of the glass bowl or shield. This carries the support higher and makes the tension less upon the terminals of the tube.

This protecting device moves easily with the tube holder and glass shield and is no inconvenience. While it does not give absolute protection either against the high tension electric current, or the radiation, it is a good step in the right direction.

X-RAY TREATMENT OF PULMONARY TUBERCULOSIS*

By WILL WILKINSON, M.D.

PHOENIX, ARIZONA

FOR the past decade *x*-ray men have been the cavalry of the great and splendid army of medical men, and I appreciate the honor of being made a member of a society all of whom are imbued with the "let's go" spirit.

It occurred to me that in one respect I am treading in the path of my illustrious confrère and fellow-townsman, Dr. Warner Watkins, who usually starts something whenever he appears before you. It is a little surprising that *x*-ray therapy is a recognized treatment for glandular, bone, skin and peritoneal tuberculosis, but has been so little applied in chronic lung trouble. The substernal lymph glands are usually the primary foci of infection, and the arrest of the disease is complete or partial in proportion to the fibrosis and calcification of chest lymph glands. Careful workers have very generally reported success in the treatment of tuberculous cervical glands. Why not give tuberculous bronchial glands the same treatment?

The proven value of the *x*-rays in unresolved pneumonia has established its place in the treatment of this disease of the chest. Furthermore, it is admitted that it is the actinic rays of the sun that are responsible for the brilliant results of solar therapy in all forms of tuberculous infection. Also we now know that the sun's rays are physically the same as *x*-rays, only much softer. I believe the greater penetration of *x*-rays makes them especially valuable in the treatment of deep-seated tuberculous foci in the lungs, and that we are really putting sunshine inside the chest.

Dr. J. D. Gibson, of Denver, was one of the pioneers in *x*-ray therapy; he gives this remedy the foremost place in the complete arrest of his own lung disease some twenty years ago. Since that time he has had a very large clinical experience with *x*-rays in office treatment of consumptives. After being in general practice in Phoenix, where about half my work was with tuberculous patients, I had the opportunity of visiting Dr. Gibson. He showed me a large number of chest plates of his patients, and, with few exceptions, the cases that persisted in the treatment showed marked reduction in the substernal gland shadows. As I went over his case records and interviewed his patients, I was convinced that they improved in appetite, weight and strength much more rapidly than my own tuberculous patients, or those of any practitioner with whose work I was familiar.

In a recent article, Dr. Gibson says: "The fact is, the *x*-ray is probably the greatest blessing ever bestowed in one agent upon suffering humanity through the medical profession. *X*-ray diagnosis has saved its thousands, but radiotherapy when properly recognized will save its millions. It has a range of therapeutic effect from producing the gentle stimulation with slight hyperemia, on to over-stimulation and inhibition, until destruction of tissues results."

Again, from the same paper: "I made the claim many years ago that the opsonic index should be controlled and regulated by means of the *x*-ray. Dr. Crane, of Kalamazoo, and Dr. McCullough, of London, have sustained this contention. Later, I ascertained that with the hyperemia and engorgement produced in tissues by means of the *x*-ray, changes developed in the tissues which had for their final effect the creation of homologous vaccine from the antigens developed within the patients' own tissues. These vaccines, antitoxins and antibodies, generated in Nature's own way, give us a most ideal autogenous vaccine."

Other writers have called attention to the

*Read before the joint meeting of the Pacific Coast Roentgen Ray Society and the Western Section of THE AMERICAN ROENTGEN RAY SOCIETY, at Avalon, Catalina Island, California, June 19, 1920.

improvement in lung trouble when only the cervical glands were being rayed, and attributed the benefit to autogenous vaccination from the cervical glands. Dr. Gibson gives a series of blood counts made on a number of cases which show a decided increase in the mononuclear cells.

A very interesting paper, entitled "Experimental Studies with Small Doses of *X*-Ray," appeared in the *Lancet* of April 26, 1919. Dr. Russ and his coworkers studied their effects upon the blood and found the mononuclears more markedly affected than the reds or polynuclears. I quote at some length his results:

"We have obtained identical results upon the lymphocytes with unscreened medium *x*-rays and with very hard rays screened by 7 mm. of aluminum.

"From the results of many experiments devised to determine the nature of the action of the *x*-rays on the lymphocytes, it has been concluded that the action is a direct one upon these cells in circulation. One such experiment was as follows:

"A rat completely screened by lead except for a region over the heart, was exposed to a parallel beam of *x*-rays; the exposure was adjusted so that the circulating blood should receive the same amount of *x*-rays as it would by exposing the whole animal for about one minute. The fall and recovery curves of the lymphocytes were obtained and charted. They were nearly identical.

"The fact that the lymphocytes disappear from the circulation in such large numbers after an exposure lasting but two seconds leads us to doubt very strongly that this is due to their destruction, especially as they reappear with great rapidity. It is not a direct local effect of the radiation upon the tissues, for no local accumulation occurs in the irradiated area, nor have we detected any alteration in the general distribution of the lymphocytes through the lungs, liver or kidneys, as they have been examined from this point of view.

"If lymphocytes *in vitro* be given a dose one thousand times as large as that required for these effects *in vivo*, no degenerative changes are detectable microscopically and no diminution in their numbers is observed.

"A rat, when given a small dose of *x*-rays (twelve seconds) shows a 50 per cent reduction of its circulating lymphocytes one hour later; then it begins to recover and in twenty-four or forty-eight hours is normal again. If the same dose is administered a fortnight later, a similar drop occurs, the recovery is slightly delayed, but the numbers of lymphocytes finally reached is generally greater than at the beginning. Repeated application of such a small dose may result in a high degree of lymphocytosis. The circulating lymphocytes in the two cases depicted have increased from 11,000 and 25,000 to 112,000 and 117,000 per cm. respectively; corresponding counts for the polynuclear leucocytes were initially 5,000 and 5,000, terminating in 10,000 and 14,000 per cm. respectively.

"There is clear evidence of instability in the blood contents of these irradiated animals, but the number of lymphocytes rarely drops so low as the normal level, even several months after the exposures have ceased.

"Exactly what are the best radiation conditions for the production of this lymphocytosis it is not yet possible to say. Large doses may eventually produce the condition, but are to be avoided, owing to their injurious nature. It is uncertain, at present, whether a small dose repeated at very short intervals produces the result. One batch of eleven animals was given small daily doses (twelve seconds) over a period of two months. The average of the lymphocyte counts before irradiation was 19,000; three days after the last dose of *x*-rays, it was 27,000, and no marked rise was detected later, although counts were made upon some of the animals for another two months.

"It has been shown in a previous publication by two of us that when sarcoma cells (Jensen's rat sarcoma) are inoculated into rats which had been previously immunized, the failure of the sarcoma to grow is associated with some special activity on the part of the lymphocytes.

"The further experimental fact acquired

was that if immune rats were given a dose of *x*-rays sufficiently large to cause and maintain a marked lymphopenia, then such immune animals became once more susceptible to the growth of the sarcoma."

X-ray workers have become sterile, and we are able to induce the menopause and sterility in women, whenever indicated. It may be that the reproductive power of the tubercle bacillus is reduced by the Gibson method of *x*-ray treatment and its virulence destroyed.

During the past seven years, I have been treating consumptives with *x*-rays and most of them were decidedly benefited. I have also had a good success in relieving winter coughs which would not respond to cough mixtures. Three to six exposures on alternate days are usually sufficient in these cases.

As an illustration, I cite the case of a young mining engineer who for four years after coming to Arizona did not improve greatly and was unable to work. In the fall of 1913, I gave him a three months' course of *x*-ray treatment. There was marked improvement in cough, and pulse dropped to eighty; by early spring he went to work and has not lost much time since. Last fall and winter he took another course of treatment, of five months' duration, with decided benefit in his general condition. The radiographs of his chest showed marked increase in peribronchial fibrosis, with scattered areas of calcification and diminution in the width of the hilus shadow.

TECHNIQUE

We give treatments three times a week, alternately exposing the anterior and the posterior chest, using 2 to 3 ma., 6 in. spark, 15 in. distance, 5 to 10 minutes time, and 3 mm. of aluminum as filter. In many cases, we begin with a dose somewhat less than the above, especially if the case has rapid heart and slight temperature, applying the lesson taught by heliotherapy, that the tuberculous patient must begin with very short sun baths.

To sum up, we believe that when *x*-ray therapy is properly used in incipient tuberculosis, especially with those who have improved or are at a standstill, most of them will be decidedly benefited. As in pneumonia, inflammation and congestion are relieved, adhesions are absorbed to some extent, lymphocytes are increased, infected lymph glands become shriveled and cease to be foci of infection. Fibrosis and calcification are promoted, the pulse rate is lowered, and the blood pressure approaches normal. With the improved circulation and elimination, patients sleep and eat better and gain in weight. Expectoration becomes at first freer and then thinner and gradually decreases. The cases progress toward complete arrest much more rapidly than they would without the *x*-ray therapy.

Later, we hope to be able to report a series of cases with blood and *x*-ray findings before, during and after courses of *x*-ray treatments.

[NOTE. The technique we are now using is 5 ma., 9 s. g., 15 in Tg. Sk. and 3 to 6 minutes time, according to temperature reaction of patient. We do not want more of a reaction than that of a light vaccination. This dose is given two or three times a week, alternately anteriorly and posteriorly.]

A ROENTGEN STUDY OF DUST INHALATION IN THE GRANITE INDUSTRY*

By D. C. JARVIS, M.D.

BARRE, VERMONT

BARRE, Vermont, being the largest granite center in the world, the opportunity to study granite dust inhalation is exceptional. A permanent residence in Barre rules out the time factor and makes it possible to carry the work to any conclusion thought advisable. Practicing eye, ear, nose and throat for the past twelve years among granite cutters, one's attention could not fail to be focused sooner or later on their respiratory troubles, and becoming interested in the problem a hospital transformer was purchased in 1917 for office use in the hope that with its assistance some knowledge might be gained of the chest condition of these men.

INTRODUCTION

The accumulation of cases was slow and the advent of The National Tuberculosis Association in the field during 1919 was welcomed. Through its Committee on Mortality from Tuberculosis in the Dusty Trades, an investigation of the granite industry was started, because it was thought that the granite industry of all the dusty trades would show the highest mortality from tuberculosis. The investigation was divided into three phases: a statistical inquiry, a mechanical process inquiry, and the medical examinations. Dr. Edward R. Baldwin of Saranac Lake is chairman of the medical work, and the writer wishes at this time to acknowledge his unfailing encouragement and helpful guidance which has made this work possible, for there are many things to be done in an investigation of this kind before 1240 men are interested and vote to appear for the actual work. Through the trying preliminaries when the work hung in the balance Dr. Baldwin's assistance was invaluable. The writer owes a debt of gratitude to Dr. Kennon Dunham for blazing the trail, as his work saved much valuable time, labor and worry. Without Prof. William Snow Miller's work on anatomy of the lungs, which was at hand for reference and study, some of the observations recorded would have been impossible. The granite cutters have shown a remarkable spirit of cooperation. They did not appear because of any illness, but came up for examination in routine order by previous arrangement. Many of them had never had occasion to consult a physician before. They were all able to work and considered themselves in good health. As the work progressed serial films of these men were suggested and from the helpfulness received from the few cases studied serially it seems advisable to extend the serial idea to a greater number. Ten years will probably be consumed before conclusions can be drawn, so at this time a preliminary report is presented on the 386 men thus far examined. This number have all been taken stereoscopically, and it is planned to continue the examinations until 1,000 have been examined

Nature of Report.—There are so many points worthy of detailed discussion that at this time only a survey of the general factors influencing the appearance of the films will be considered. As soon as possible separate studies of the apices, annular shadows, mediastinum, heart shadow, hilus, diaphragm, and Dunham's fans will be reported, but in the present paper only a general development of the lung lesion will be considered.

REVIEW OF LITERATURE

Roentgenological.—In this country at least

*Read by invitation at the Twenty-first Annual Meeting of THE AMERICAN ROENTGEN RAY SOCIETY, Minneapolis, Minn., September 14-17, 1920.

very little seems to have been done in systematically investigating a dusty trade by means of the roentgen ray. The work at Barre[1] represents the first work of the Committee on Mortality from Tuberculosis in the Dusty Trades. The only other investigation is represented by the valuable contribution to be found in *United States Health Bulletin No. 85*, issued January, 1917, comprising *A* reference to the roentgenographic appearance of the lungs in dust inhalation except in Barker's article in *Monographic Medicine* in which a brief reference was made. He states that the text books on roentgenography consulted were all silent except Robert Knox and Rieder. He was able to find only one journal article, and that by a German writer who reported five cases. In 1918, in the

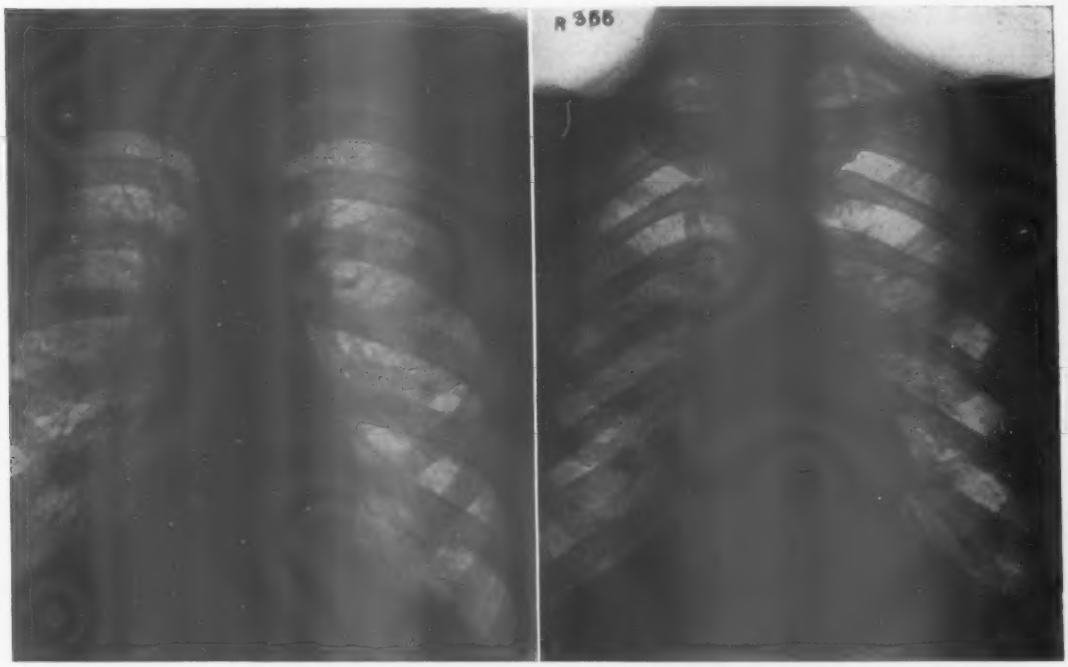

Fig. 1 (130). Exposure eighteen years. Granite Pneumoconiosis stage B. Notice peribronchial thickening which is so common in granite cutters with complete absence of constitutional symptoms.

Fig. 2 (355). Exposure eighteen years. Granite Pneumoconiosis stage C.

Clinical Study of 433 Cases of Miners' Consumption among Zinc Miners in Southwestern Missouri, by A. J. Lanza, with a chapter on Roentgen Ray Findings in 150 Cases, by Dr. Samuel B. Childs of Denver. In THE AMERICAN JOURNAL OF ROENTGENOLOGY for June, 1917, Dr. W. W. Boardman reported three cases dealing with dust inhalation. After a thorough search of the literature he comments on the fact that it seems to be remarkably free from any discussion of this subject. He states that in the standard works on clinical medicine there was no

March number of THE AMERICAN JOURNAL OF ROENTGENOLOGY, Pancoast, Miller and Landis reported 137 cases gathered from eight industries. Abroad one finds *The General Report of the Miners' Phthisis Prevention Committee of South Africa*, published under date of March 15, 1916. In this report of 189 pages only three and one half are devoted to a report of the 8,000 radiographic examinations made. It is not stated whether the exposures were made stereoscopically or not. The work of Collis[2] in England devotes very little space to the roentgenographic phase, being more in the nature of a statistical study.

Pathological.—The South African *Report* states that "it is important to understand the distribution of the lymphatic channels since it is by their means that dust particles which have been conveyed into the lung are distributed through the organ." Intermediate silicosis may be defined as a diffuse fibrosis due to the gradual accumulation of mineral

Fig. 3 (129). Granite fibroid pneumoconiosis stage A. Exposure twenty-five years.

particles in the lymphatic capillaries as a result of chronic obstruction of the lymphatic circulation. Dr. LeRoy Gardner of Saranac Lake Laboratory is in charge of the pathological work connected with the investigation and the following extract is from his paper read before The National Tuberculosis Association at its annual meeting in 1920:

"In guinea pigs after about three weeks' exposure small amounts of dust may be found enclosed in mononuclear intro-alveolar cells which often show mitotic figures. These cells are scattered everywhere in the alveoli from the pleura to the hilum. At about two months some of these intra-alveolar cells have begun to mobilize and have formed considerable collections of cells often so closely packed as to simulate giant cells. These cell masses lie in the alveoli along the course of the ductuli alveolares and about and within the small lymphoid collections occurring in the periphery of the lungs. As Miller has shown, such collections occur at the distal ends of the ductuli alveolares and at the division points of the vessels. Dust has already passed through the lung and lodged in small amounts in the tracheo-bronchial lymphatics. From three to seven months the same process continues with a steady increase in the amount of dust deposit. The invasion of the lymphoid tissue of the lung is more extensive and the larger nodules at the bifurcation of the bronchioles and bronchi become involved. All of the lymphoid tissue of the lung becomes very active and mitotic figures are very common even in the normally small peripheral collections. If the animal be set aside after dust exposure the lung makes rapid and effective effort to rid itself of the irritant. The clearing process has only been observed up to three months in animals dusted for seven months previously, but at that time practically all the dust is collected within large aggregations of round or oval mononuclear cells which lie in the immediate vicinity of much enlarged lymph nodules. Heavy deposits occur within such nodules and within the tracheo-bronchial lymph nodes.

Composition of Barre Granite:

Silicon Dioxide	69.56
Aluminum Oxide	15.38
Iron Oxide	2.65
Magnesia Oxide	Trace
Calcium Oxide	1.76
Sodium Oxide	5.38
Potassium Oxide	4.31
Manganese	Trace
Loss on ignition, CO_2 and moisture	1.02
	100.06

"According to Gardner[4] when examined under the microscope the unscreened dust may be roughly divided into large and small particles. The former, which could not possibly be concerned in an inhalation experiment,

Fig. 4 (227). Exposure thirty-three years. Working every day. Granite fibroid pneumoconiosis stage C. Only symptoms slight cough, slight expectoration. Physical examination negative.

show an average size of 82 by 84 microns (ocular micrometer measurement). The smaller particles average 4.3 by 6.3 microns with a minimum of .028 by 1.4 microns by actual measurement. In shape the particles may vary greatly. Some are flattened polygonal masses with sharply cut edges and corners. Others are rod-shaped, often slightly curved, with sharply horizontal or square cut ends. Frequent vegetable cells and fibers are noted."

Samples of dust resulting from the use of the pneumatic tool have been examined by means of a small giant magnet made by the Victor *X*-Ray Corporation, and considerable steel has been extracted from a given quantity by means of the magnet, 2 drams of granite dust yielding 2 grains of steel. From this experiment it will be seen that we are dealing with two kinds of dust, that from the stone being worked and that from the tool used in working it, giving rise not only to a silicosis but to a siderosis as well.

PRESENT PROBLEM

In 1915, we find in Barre 2,050 granite cutters working, while in 1919 we find only 1240. The question suggesting itself whether this condition was peculiar to Barre alone, the total number of cutters for the United States was investigated and it was found that there was a corresponding diminution in the number of cutters throughout the whole country. For a number of years before the war immigration showed a decrease, and for the same number of years the number of entering apprentices was also very small. The statistician returned the report that an analysis of the death certificates for the past twenty years in Washington County indicated that 86 per cent of the cutters died from tuberculosis. The roentgen ray study was undertaken to assist in determining the incidence of tuberculosis among living cutters.

Technique.—It was annoying to develop the films of the cutters taken during the day only to find that there was such a variation in the quality. Exposures were made basing the changes in technique upon the difference in weight that the men presented, but this necessitated so much attention to the details of developing, offsetting over-exposure in some instances and under-exposure in others, that it was finally decided to make every factor constant except that of time, and a detailed set of measurements was instituted in order to discover if possible a measurement or measurements upon which exposure time might be based. Measurements were taken as follows: From the fifth dorsal vertebra by means of a pelvimeter to a corresponding point upon the sternum, from the left nipple to a corresponding point upon the scapula, from the sixth rib in the axilla to a corresponding point in the opposite axilla. These measurements were entered in the appropriate columns and with them the weight and height. The films were then developed in Eastman developer, using standard time and temperature, and the results noted. Two hundred and thirty-five sets were necessary before the table was worked out, and the day's work showed uniform quality regardless of weight or height. At first thought it was felt that the measurement through that part of the chest representing lung area would be the most satisfactory, but with the complete data at hand whenever the fifth-dorsal-to-sternum measurement coincided in the day's work the films showed the same quality, but when other measurements coincided the quality varied greatly. By means of a pelvimeter the chest expansion was watched in the areas representing the original measurements and it was found that the spine-to-sternum measurement changed very little, while the variation of the scapula-to-nipple measurement was influenced by the position of arms and inspiration. Consequently the fifth-dorsal-to-sternum measurement was adopted as the basis of estimating the patient's exposure time. These cutters were a splendid type physically, and while the table has been worked out on these muscular men it still holds good for the patients coming in the ordinary office practice. The technique is as follows:

Spark Gap—3½ inches.

Coolidge 30 M. A. Tube run at exactly 30 M. A., the hand being on the tube rheostat constantly during the exposure to make any adjustment needed at once.

Distance from tube target to film using upright stereoscopic shift 30 inches.

Developer time 5 minutes.

Temperature of Eastman developer 66° F.

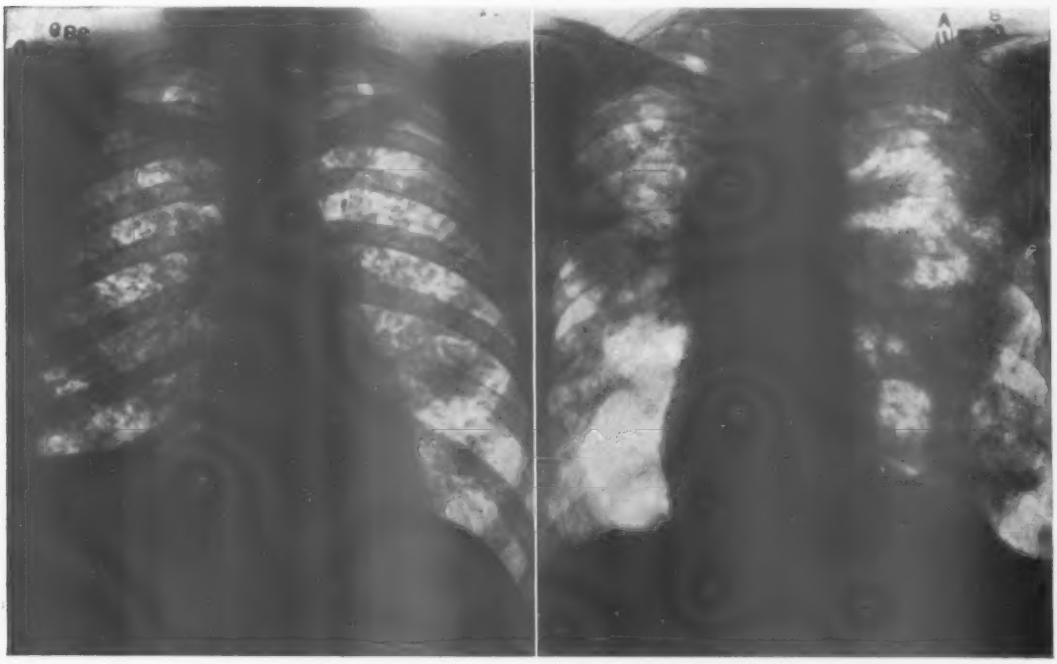

Fig. 5 (389). Fifty-two years of age, working every day. Exposure twenty-eight years. A professional swimmer, his last race being at age of thirty years, and the distance one mile. Sputum negative. Physical examination negative. No symptoms.

Fig. 6 (A.S.—11-5-20). Exposure fifty years. Repeated examination of sputum negative. Marked dullness all over base. Deficient breathing. Scattered bronchi.

Using the above constants the following measurements and time produced results:

FIFTH-DORSAL-TO-STERNUM

	Time by Time-Switch
6 inches	1½ seconds
6½ inches	2 seconds
7 inches	2½ seconds
7½ inches	3 seconds
8 inches	3½ seconds
8½ inches	4 seconds
9 inches	4½ seconds
9½ inches	5 seconds

In estimating the point upon the spine through which to pass the principal ray of the second exposure the lung is percussed down to absolute dullness on the back and the junction of the lower third with the middle third selected as the point for the passing of the principal ray of the second exposure. The tube stand is then elevated as usual for the first exposure. To avoid the clavicle in the apical region the suggestion of Dr. Bray of Raybrook Sanatorium has been adopted, namely, that of having the hips grasped between the thumb and forefinger of each hand and the shoulders thrown forward without elevation against the stereo shift. The patient is given a toy noise-maker such as is used when showing lantern slides, and is directed to signal as taught by Mr. Sampson of Trudeau Sanatorium when patient has taken a moderately deep breath and is ready to cooperate by holding it during the time necessary to secure both views of the stereo set. Patient signals when told that operator is all ready and is not allowed to breathe between the exposures of the stereoscopic set.

Classification of Films.—An effort was

made to prove that these men had tuberculosis, but not being able to do this it was found necessary to accept the diagnosis of pneumoconiosis, and a continued study of the films seems to bear out this diagnosis. A classification being more or less imperative in order that the films be studied systematically the following was decided upon:

Granite Pneumoconiosis Stage A
Granite Pneumoconiosis Stage B
Granite Pneumoconiosis Stage C
Granite Fibroid Pneumoconiosis Stage A
Granite Fibroid Pneumoconiosis Stage B
Granite Fibroid Pneumoconiosis Stage C
Granite Tuberculous Pneumoconiosis Stage A
Granite Tuberculous Pneumoconiosis Stage B
Granite Tuberculous Pneumoconiosis Stage C

It seems advisable to use the term Pneumoconiosis, as the two Greek words from which it is derived signify Lung Dust, which really represents the condition being studied, while the term Phthisis is apt to convey as many meanings as it has pronounciations. While the term Silicosis has been used it seems advisable in the interest of efficiency to use the term Pneumoconiosis and in connection with the qualifying adjective Granite, as the term Granite Pneumoconiosis suggests at once the nature of the lung lesion under consideration, the manufacturing process, percentage of silicon dioxide in the dust and the type of workman. The second classification, Granite Fibroid Pneumoconiosis, suggests not only the nature of the lung lesion and the industry in which it occurs but also the progress which the lesion has made. The third classification, Granite Tuberculous Pneumoconiosis, suggests the causative factor in producing the original lung lesion, the industry responsible for the lesion and the fact that tuberculosis has been superimposed upon pneumoconiosis. Taking up the various subdivisions under each main classification we first consider "Stage A" under the classification "Granite Pneumoconiosis." The films coming under this have a hilus density easily discernible and linear markings going to the first and second interspaces and increased perivascular markings in the bases. It is found that even outside of the industry the Barre residents examined as controls fall into this class as we have a dust hazard in the general atmosphere of the town, "Stage B" includes films that show linear markings radiating in all directions from the hilus to every part of the lung reaching almost to the periphery. "Stage C" in addition to the above shows a homogenous haziness over each lung between the linear markings. Under the classification "Granite Fibroid Pneumoconiosis Stage A" are included films showing a fibroid area not larger than 3 centimeters, "Stage B" films showing a fibroid area not larger than 6 centimeters, and "Stage C" films showing fibroid areas larger than 6 centimeters in their longest diameter. The classification "Granite Tuberculous Pneumoconiosis Stage A" represents minimal tuberculosis, "Stage B" moderately advanced and "Stage C" far advanced tuberculosis superimposed on granite pneumoconiosis.

Dust Exposure Periods of Men Examined.—The length of time that granite dust had been inhaled was represented by four months in one cutter and the maximum time by fifty years in another.

FACTORS INFLUENCING THE APPEARANCE OF THE FILMS

Mouth Breathing as a Factor.—It was most perplexing to find cutters with equal number of exposure years and working under the same conditions showing such marked differences in the appearance of the films. It became quite evident that given the number of exposure-years one could not even hazard a shrewd guess with any degree of success as to the probable appearance of the *x*-ray film. According to the experience of Watt, Irving Johnson and Steuart[5] the mouth-breather is more apt to develop silicosis than one who employs nasal respiration. Particular interest has been taken in keeping detailed data of the upper part of the respiratory tract, hoping to show the influence the nose and throat played in the de-

veloping of pneumoconiosis. All this data will be reported at another time, but it is sufficient to say that the defensive mechanism of the upper respiratory tract breaks down fairly early in granite dust inhalation. An adaptation of the upper resipratory tract to occupation takes place, an anesthesia of the tract developing as evidenced by the inability of a cutter to feel a pencil point when drawn across his pharynx. One may hold a throat mirror in viewing the larynx for an indefinite length of time, the cutter stating that he feels nothing in his throat. In view of these facts one wonders how efficient the cilia are, and with the sensory nerve endings of the trachea and bronchi anesthetized by adaptation to occupation there is absence of cough of irritation, thus encouraging the dust to remain in the lungs. Particular attention has been paid to noticing whether the men coughed while undergoing the examination work connected with the *x*-ray phase, and one could not fail to observe the almost entire absence of coughing among the men. The films belonging to the cutters showing mouth-breathing were separated from those showing nasal breathing, and a study was made comparing them with other films of the same exposure-period, with the result that one cannot help but observe that the films belonging to the mouth-breathers show a lesser lung lesion than nasal breathers. The explanation is that the usual curve of the inspired air is broken by mouth-breathing and the dust impinging upon the posterior pharyngeal wall is expectorated as soon as the accumulation warrants it, or is swallowed, with the result that very little of it reaches the trachea and the lungs are consequently spared.

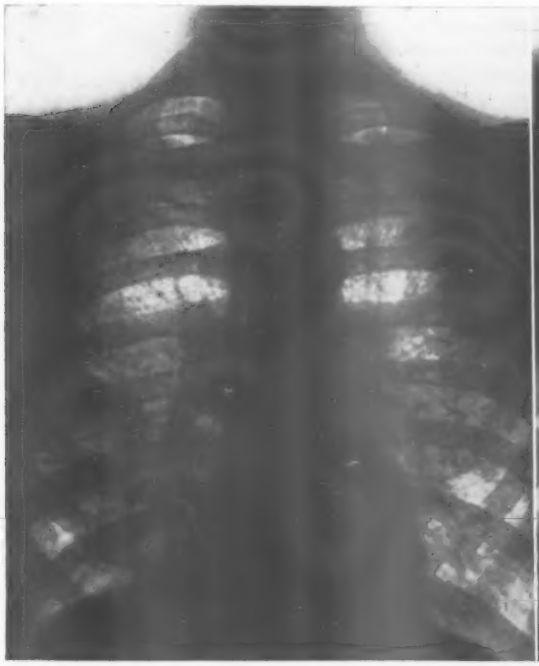

Fig. 7 (185). Exposure thirty years. Ambidextrous. Even lesion both sides of chest.

Fig. 8 (58). Exposure twenty-seven years. Showing basal condition starting in left base. Notice calcification of ribs so common in cutters.

Nationality as a Factor.—It was noticed while looking over an accumulation of films representing several days' work that a fairly large number of them showed less density than the others. This seemed strange because the cutters appearing for examination during the three-day period represented were all men with an advanced exposure history. Laying the better films aside and referring

to the examination blanks it was discovered that the majority of these films were those belonging to Italians. It being felt that the constant viewing of films had blurred one's ability to appreciate different densities, the films were taken to a granite manufacturer with the request that he look them over and lay aside those showing less white in the lung field, paying no attention to shadows which represented the heart, ribs, etc. To my surprise his collection of films which he designated as better contained those of the Italians. Ten nationalities are represented in the examination work and the films were now studied from this angle with the result that they were found to line up somewhat as follows in order of excellence: Italians, Americans, English, Spaniards, Scotch, Swedes, Norwiegans, Danes, French and Irish. You will notice that there is a geographical distribution of these races, many of the better ones living in Southern Europe and many of those along the last of the list living in Northern Europe. They may be also classified on the basis of those living in dusty countries and those living in countries not so dusty. It cannot be denied that in the granite industry at least the Irish are punished severely, and it is a question whether they should be in a dusty trade—certainly not in the granite industry, as they represent a hazard under the present working conditions and should not be accepted as apprentices. In looking about for an explanation of the difference in susceptibility of the different nationalities one has a feeling that in the chests of the Italians the dust is filtered out so rapidly that it never is other than an irritant, while in the Irish for example it passes the irritant stage and becomes a foreign body.

Fig. 9 (177). Exposure fifteen years. Showing right basal condition just starting.

Fig. 10 (750). Right basal condition farther advanced. Exposure thirty years. Patient died two months later. Death occurred suddenly during night. Cardinal symptom was dyspnea.

Occupational Position as a Factor.—In studying the films two areas always showed an increase in density in linear markings in earlier stages, and as the lung lesion advanced this difference in density held good up to the point where the whole lung area on both sides was involved. These areas of increased density were represented by the portion of the lung field just below the left

clavicle and at the right base. In endeavoring to explain this increased density in these situations the occupational position of the men was studied and it was found that the pneumatic tool they use vibrates 3,200 times a minute, and in order to secure a basal support that the tool might be used to the best advantage the upper part of the right chest is compressed by the right arm and elbow and the lower part of the left chest is compressed by the left elbow and forearm. This apparently limits the respiratory action of the portions of the chest, and palpation of the same at work shows limited expansion in the compressed areas thus allowing more dust to find a resting place in that portion of the lung receiving most air. It has been stated by other observers that the progress of the lung lesion was greater on the right side below the clavicle, but the experience in Barre would lead one to suspect that the occupational position of the workers examined was different from that of the granite cutters. It would seem, then, that occupational position is a factor in determining the part of the lung in which a lung lesion from inhalation of granite dust has its inception.

EVIDENCE GAINED FROM NON-SERIAL FILMS

In a work of this kind one must of necessity study non-serial films, because it takes a cutter thirty years to produce a lung lesion which would be diagnosed if he had constitutional symptoms as lobar pneumonia. It takes him between twenty and twenty-five years to produce a lung lesion which would be diagnosed as broncho-pneumonia if he had constitutional symptoms. It is manifestly impossible to follow an individual cutter by means of serial films through thirty years of granite dust inhalation. For labor turnover, the migratory nature of the cutter and the ever recurring strikes necessitating his seeking employment in other industries for the time being at least, and from which he often fails to return if the occupational environment is congenial, are conditions incompatible with serial films extending over

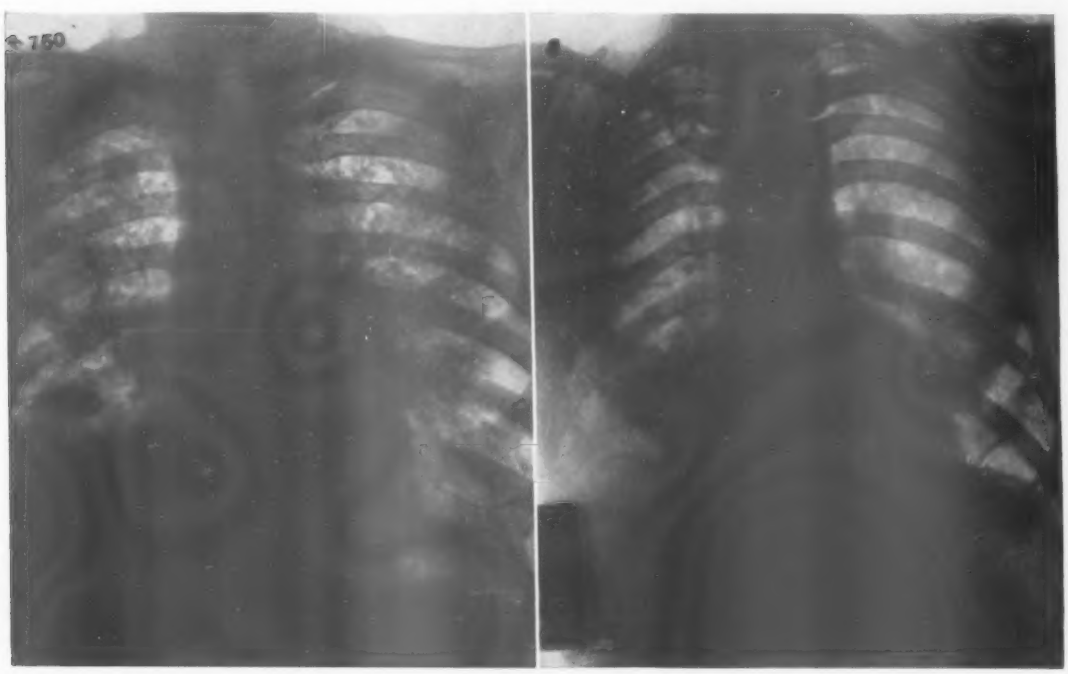

Fig. 11 (319). Exposure thirty-two years. Showing progress of right basal condition. No symptoms.

Fig. 12 (270). Exposure thirty-five years. Taken September 8, 1919. Notice right basal condition.

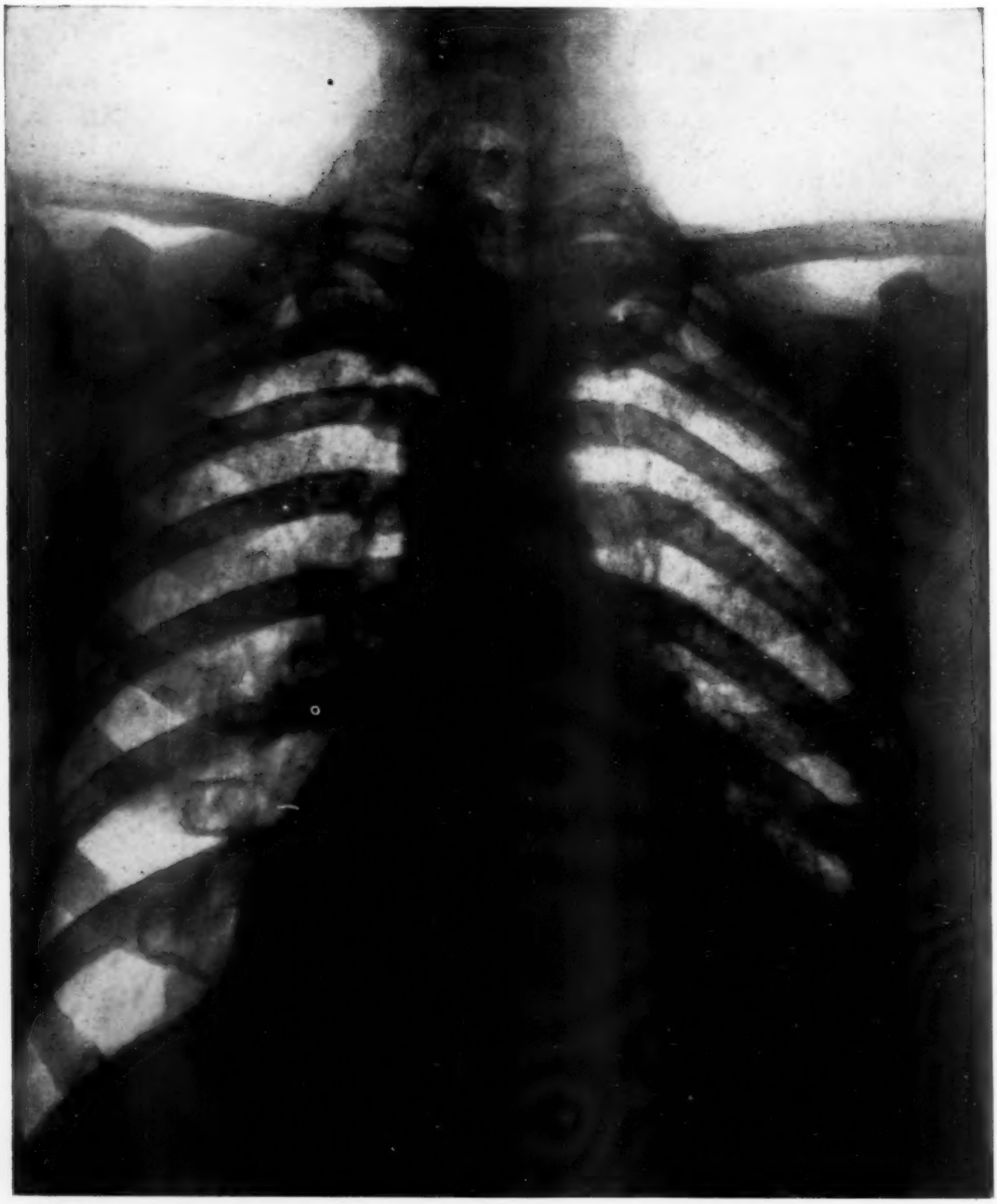

Fig. 13 (No. 160). Same patient as Fig. 12. Taken after two months' absence from granite industry. Note change in appearance of right base.

Fig. 14 (375). Same patient as Figs. 12 and 13 Taken five months after re-entering granite industry. Notice reappearance of right basal condition, on exposure again to dust.

any period of time. An effort is being made to select men who for various reasons will be expected to retain a permanent residence in Barre and take them serially, so that in the same individual the lung lesion may be traced from stage to stage. It is hoped to continue this until at least the pathological process observed in one cutter overlaps that seen in another. In the few instances where it has been possible to observe the lung lesion by means of serial films of the same cutter, the evidence has borne out the inferences made by studying several hundred non-serial films.

It is quite evident from this study why it is impossible to describe a normal or standard hilus. It would be as difficult as to describe a normal day or a normal reading of an outside thermometer. We learn to vary our sense of normal with the changing seasons of the year. In like manner we learn to vary our sense of normal so far as a hilus is concerned as the respiratory environment of the individual changes. A normal hilus for a granite worker is never seen because his intake of dust is changing from week to week, especially if he is experienced enough in the work to be an all-around man. If he is he uses varying processes of creating the finished product, depending upon the process he is detailed to for the time being. So one does not try after a while to describe a normal hilus, but rather looks upon the hilus as his lung indicator, telling what has gone on before and what is now going on. The hilus then represents the peripheral reception of the irritant, and in the case of the granite cutter it is a mechanical one with no ability to proliferate and no ability to produce toxic products for absorption with their production of constitutional symptoms.

The pathology seems to be the same whether the irritant is mechanical or bacterial, only in case it is bacterial the lung lesion is accelerated so that in a few days or a year at most results are produced that it takes years to produce with a mechanical irritant. In proportion to the amount of dust that is brought to the periphery of the lung by way of aspiration, in like proportion will the hilus show a change in increased area and density. On this point we feel sure, because we have seen in the same cutter the hilus diminish in size because the cutter was obliged to loaf owing to a severe eye injury, and on his return to the industry we have seen the hilus increase to the original size when inhalation of dust was resumed. With the hilus the lymph node nearest the hilus underwent a change, emptying during the loafing period and taking on its function and reappearing upon the film when work was resumed. These observations lead us to believe that the extension of the lesion is not from the hilus outward *per se*, but rather that the lesion is peripheral all the time, and the hilus change as to speed shows us how great the peripheral severity is.

As the hilus continues to act as an indicator of the dust brought to the tracheobronchial lymph nodes by the lymphatic system of the lungs, there comes a time when the first set of lymph nodes external to the hilus take on their function, being visible to the eye on the film as the cervical lymph nodes are palpable when they take on their function. As the study extends we are able to make out three sets of these nodes from hilus to periphery. For the sake of description these lymph nodes have been called "proximal set," "medial set" and "distal set." Now using one of these proximal lymph nodules, as we shall call them, for an apex of a triangular area, we shall find the base formed by two medial nodules of the same character. In turn using one of these medial nodules for an apex we shall again see the base of a triangular area formed by two lymph nodes, but this time they will be those of the distal set. The sides of these triangles are formed by linear densities.

From these triangular areas which at first contain the lung markings seen in the lung as a whole, we see Dunham's fans develop. If one is at all skeptical about the occurrence of Dunham's fans he will soon have that skepticism removed if he studies the films of

pneumoconiosis of a number of workers, for they are seen unilateral, bilateral and in almost any part of the lung. The right lung from apex to base seems to be able to accommodate five at one time with the bases to the pleura and the apices to the hilus in all except the lowest, which has its apex pointing toward the diaphragm. If one lays aside all of the films having a fan in the same area and then studies them the evolution of one of these fans will be watched until it occupies practically the entire upper left lobe with a stem extending back to the hilus as large around as a pencil. One has a feeling as the linear markings are studied that they are perivascular rather than peribronchial, because in cutters exposed for twenty years and then out of the industry for a period greater than five years, the bronchial twigs can be made out as an area of lesser density to the inner side of the linear markings. The inner boundary of the bronchial twig is seen as a thin white line, but there is no area of greater density accompanying it. These bronchial twigs can be followed quite a distance out into the lung structure. In regard to what is spoken of as peribronchial thickening we have seen it change during the ten weeks' strike in 1920, becoming lessened in width and irregular in border as the dust deposit was unevenly moved on to the hilus.

Considering the lung lesion as it affects the proximal medial and distal sets of lymph nodules described, we first notice the proximal node appearing when the hilus has increased in width, reaching near this nodule. At first this nodule looks like the end of a cotton wound applicator and is adjacent to a bronchus on end. From its size of about six mm. in diameter it increases until it takes on the appearance of a tuft of absorbent cotton, its edges being blurred and irregular, the original density being perceived near the center as an area of slight increase in density over the surrounding area. About the time this is 2 centimeters in width the medial node appears and undergoes a change similar to that of the proximal node. In turn the distal node appears, and as it undergoes its increase

Fig. 15 (166). Exposure twenty-eight years. Bilateral Dunham's fans each involving first interspace trunk both sides.

Fig. 16 (91). Exposure twenty-six years. Stage 5 of one of Dunham's fans. Note the pleural detour.

in area and density a haze will be noticed in the extreme periphery of the lung. This haze when viewed stereoscopically will be seen to occupy the plane of the pleura, while the lung density will be seen in its true plane. In the same individual, by means of serial films, this density was seen to appear in seven months. In another individual it was seen by the same method to disappear to a large extent during a two months' absence from his work. This area seems always to be triangular with its base towards the lung periphery and its apex towards the hilus. It has been felt that this density appearing in the pleural level is a detour of the lymph flow; the path between the periphery and the hilus being blocked, nature seeks to accomplish her end, namely, the removal of the irritant, by making a detour by means of the pleural lymphatics. This pleural haze has been seen extending from apex to various rib levels. An effort has been made to write down the evidence as gathered from a preliminary study of the films. Each one of you will probably correlate it with your own past experience and will probably draw your own conclusions.

Fig. 17 (96). Exposure twenty-six years. Working constantly. Dullness left apex. Patch of pleurisy below left nipple. Otherwise negative.

SUMMARY

1. Film densities are influenced by mouth breathing, nationality and occupational position.

2. The machinery must be considered as a source of dust as well as the material being worked.

3. A standard exposure technique should be adopted as early as possible in a study of dust inhalation in order that one may feel sure of variations of density.

4. While classification of films is helpful, the lung lesion in a dust worker is like the shifting sand of the sea and each film should be judged by its own individual densities as portraying the pathology in the making in that particular individual.

5. Evidence tends to show that the lesion always remains peripheral and the lung reaction to an irritant is evidenced by densities appearing from the hilus outward.

6. It seems possible to parallel films of tuberculosis, pneumonia and various other pathological conditions of the lungs with the films of granite cutters, there being an absence of clinical activity in the latter, the mechanical irritant producing the same lesion as a bacterial one.

7. It would seem that many densities are being diagnosed as tuberculosis which should be considered as densities of pneumoconiosis.

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THE X-RAY SHADOWS OF LUNG SYPHILIS AND SYPHILITIC-TUBERCULOUS SYMBIOSIS IN THE LUNGS*

By W. WARNER WATKINS, M.D.

Pathological Laboratory

PHOENIX, ARIZONA

WITHIN the past five years, thoracic syphilis has assumed a place of importance in clinical medicine, and our position as leaders in medical research makes it expedient that we give this subject more serious consideration. Attention has heretofore been concentrated upon lesions of the heart and aorta to the unjust exclusion of those which occur in the lung. Up to 1916, the references to pulmonary syphilis in the roentgen literature were remarkable for their scarcity, consisting of case reports from Dachtler,[1] Carman,[2] Pancoast,[3] Dunham,[4] and, possibly, others.

Pathologically, invasion of the lungs by syphilis was recognized by Virchow,[5] Depaul[6] and Pancritius,[7] and described in some detail by Fowler[8] and Stanley.[9] Clinically, many authors have directed their attention to it; some of these, like Osler[10] and McCrae, regard the condition as extremely rare and infrequently recognized, while others consider it to be relatively common. Dieulafoy[11] says "syphilis of the lungs is of the highest importance" and describes six forms, with very discouraging comments on diagnosis. The value of roentgenography for this purpose was brought to the attention of clinicians by the reports from the roentgenologists mentioned, and most writers since have emphasized the fact that the nature of the disease should make it amenable to *x*-ray differentiation. In spite of isolated reports, however, our specialty, as a whole, has taken the position that we can offer little assistance. If this were true, Carrera's[12] statement that the ultimate diagnosis of lung syphilis must wait on the necropsy and microscope would be the correct and hopeless outlook, for clinicians have already exhausted their physical and laboratory methods, and, if we cannot assist them, lung syphilis is likely to remain the *bête noire* of the internist.

However, this challenge presents too fine an opportunity for us to ignore. If we grant that lung syphilis is a clinical entity and comparatively frequent in occurrence; that the pathology in the lungs is characteristic in histologic change and in gross location; then the lesions should certainly be recognized on the radiograph.

This paper presents its material in two parts: I. Lung Syphilis; II. Syphilitic-Tuberculous Double Infection in the Lungs.

PART I. LUNG SYPHILIS

In 1916, we began a systematic search for lung syphilis by including this disease as a possibility in every lung examination, as there seemed to be no mechanical or biological reason for the frequently assumed freedom of the lungs from this infection. Inasmuch as roentgenographic interpretation consists purely of conclusions regarding tissue pathology, drawn from the shadows cast by disease changes, and since the antecedent pathological work on lung syphilis was "fragmentary and vague,"[13] the *x*-ray work necessarily was imperfect. However, several fundamental facts aided in forming a nebulous expectation of the shadows of lung syphilis.

1. The peculiarities in the anatomical structure of the lung, as demonstrated by Miller, with the relations between bronchi, arteries and lymphatics, have an intimate bearing on the interpretation of the shadows of all pulmonary lesions, including lung syphilis.

2. The characteristic method of invasion of active syphilis, wherever found, by ex-

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tension along the arteries, is distinctly different from the extension of tuberculosis through the lymphatics. A consideration of the relations of lymphatics and arteries to the pulmonary subdivisions which are involved, indicated that there would be a distinct difference in the shadows of these two diseases.

Fig. 1 (Patient 785). Peribronchial fibrotic type of lung syphilis. History of syphilis; Wassermann positive; sputum negative; abatement of lung signs under mercury.

Fig. 2 (Patient 14552). Hereditary syphilitic. Early form of infiltrative type in the left base.

3. Aside from the pathological differences, the clinical observation had been that the lesions of tuberculosis and syphilis occurred, as a rule, in different parts of the lung, the former in the upper and the latter in the lower lobes.

4. The characteristics of the shadow of tuberculosis being already definitely established, the differentiation would be between syphilis and other less common types of lung disease.

Basing our observations on these facts by selecting patients known to have syphilis and making a careful study of the pulmonary densities presented by them, certain types of shadow could, with a fair degree of probability, be classified as syphilitic. Then, by observing the resolution of such shadows after antiluetic treatment, the tentative observations could be confirmed as definitely as we could ever hope to confirm them during the life of the patient.

The handicap of a lack of accurate pathological knowledge was, to a large extent, removed by the publications of Warthin[13] on latent syphilis, in 1918, and the more recent observations of Carrera[12] on the specific lesions in the lung. It should be a matter of satisfaction to those pioneer roentgenologists who interested themselves in this supposedly rare condition, to observe that these belated pathological researches verified the accuracy of their radiographic forecast of tissue changes. The most important result of the pathological work was the furnishing of a basis for accurate classification of radiographic shadows and a definite explanation of some peculiar shadows which had been observed but not, heretofore, interpreted.

In terms of clinical pathology, we can distinguish three types of radiographic shadow produced by syphilitic invasion of the lung. The classification here differs slightly from that previously offered, in order to conform to recent discoveries.

1. The lesions of active or early syphilis produce shadows which are to be interpreted as (a) gummas, or (b) inflammatory consolidation or infiltration. Such shadows vary according to the virulence of the infection and the rapidity of the invasion.

2. The lesions of old, latent or hereditary syphilis produce shadows which represent (a) interstitial peribronchial or peri-arterial fibrosis, or (b) dense fibrosis of the lung or pleura.

3. In conjunction with thoracic syphilis, indefinite lung densities occur, the nature of which have not yet been determined, either by clinical observation, pathological research or radiographic characteristics. These densities correspond to those seen by Dachtler[1] in his cases reported in 1912.

The wide variation in the shadows of lung syphilis, from a simple peribronchial deposit of fibrous tissue in a limited lung area, to complete consolidation of an entire lung, is explained by Warthin's[13] distinction between the pathology of active syphilis and of latent syphilis.

When active syphilis invades the lung, there is extensive consolidation or inflammatory infiltration, usually in the lower lobe, due to the tendency of this infection to follow the larger arterial trunks. This localization, however, is not absolute, the first case in our records involving the upper left lobe. The shadows of this form of the disease may simulate those of primary carcinoma, or the partially resolved consolidations of pneumonia. The shadows are usually confluent, of varying density, inclined to irregularity and mossiness of the edges, and tend to mass along the heart border and large bronchial trunks. They may be confused with the shadows of bronchiectasis, abscess or pneumoconiosis.

When tissue resistance is sufficient to encapsulate the diseased area, gummatous lesions result. The shadows of gummas will vary in size; will usually be multiple; are not confluent; will have edges slightly irregular but more definite than consolidations; when caseous, they will have centers of diminished density; when healing, they become irregular in outline, show pointed projections of fibrous tissue which contract the lung and may obstruct bronchi. It is conceivable that gummas may be so thoroughly encapsulated that they will remain smooth in outline and heal without material effect on the surrounding lung tissue.

The interstitial or peribronchial fibrosis, with its end result of dense fibrosis of the lung and pleura, occurs in latent syphilis, where a slow inflammatory reaction, ending in fibrosis, is the typical pathology. This fibrosis may be peribronchial or peri-arterial,

Fig. 3 (Patient 95). Syphilitic infiltration of the upper left lobe.

Fig. 4 (Same patient as Fig. 3). Shows change under antileutic treatment.

but resulting shadows will be the same, consisting of fine or coarse linear striations, springing usually from a dense hilus shadow and radiating to the periphery. The striations may occupy a limited area or involve both lungs generally. Other diseases and irritants, like poison gas, may produce a similar fibrosis.

Indefinite lung densities are frequently found in association with cardiac or aortic syphilis. Both Warthin and Carrera described lung changes which correspond to such densities, but were undecided whether they represented inflammatory reactions or passive congestion from mechanical conditions. While we wait on the pathological determination of this point, we wish to record our conviction that, radiographically, these densities are specific inflammatory reactions, and have been seen to disappear under antiluetic treatment. This has been observed both when they were found in connection with aortic disease and when they occurred in lungs without visible cardiac or aortic involvement. There are, of course, radiographic densities which are the result of passive congestion or pulmonary edema from cardiac embarrassment in syphilitic valve disease, but there should be no difficulty in differentiating these.

Since radiographic visualization of tissue change is only one of the many physical methods of investigating disease it would, manifestly, be improper and even impertinent to venture unqualified diagnoses of lung syphilis from radiographs alone. We need to take into consideration the personal history, the clinical evidences of systemic disease, the possible accompanying involvement of the heart or aorta, the other physical signs of lung disease, and the laboratory findings. However, the roentgenologist, as a consultant, has just as much right to consider all these evidences in connection with his special investigations, and produce the completed result as a diagnosis, as the clinician has to appropriate the radiographic interpretation and use it to connect his otherwise incomplete chain of evidence. In other words, we need to follow the teaching of a former distinguished President of this Society[14] and conduct ourselves as consulting diagnosticians.

Up to August 1, 1920, we have on record approximately 6500 examinations of the chest and heart. In this number we have made, or assisted clinicians in making, diagnoses of pulmonary syphilis in 172 patients; that is, of patients radiographed for suspected heart or lung disease, about 2.6 per cent had pulmonary shadows which we could reasonably conclude were due to uncomplicated syphilis. Many of these lesions were in combination with cardiac or aortic syphilis; in others there was no visible heart involvement. It will not be the function of this paper to enter further into statistical report or classification of these cases.

Part II. Symbiotic Infection

The characteristics of the tuberculous shadow are well known, and there is need to review them only so far as necessary to establish a basis of comparison with those of syphilis. Many illustrations, such as the goldenrod, the dandelion and the sunflower, have been suggested to fix the picture of the shadow of tuberculosis in our minds. The incongruity of illustrating disease pathology by means of a flower impels me to suggest a more appropriate simile. A thickly leaved tree, like our Western cottonwood, with a caterpillar web enmeshing numerous leaves and small twigs, sometimes large branches, graphically illustrates the tuberculous lesion; the shadow of this on a concrete pavement, with the sun at medium height, is an excellent representation of the radiographic reproduction. The leaves are the secondary lobules of Miller, the twigs and branches being the bronchi and accompanying vessels. Now, if we can fancy some destructive influence which blocks the circulatory system of these branches, so that the leaves wither and die, without web formation, we shall have an illustration of syphilis of the lungs, and the differences in their fundamental pathology.

As a general rule, tuberculosis, uncomplicated by mixed infection, will invade the upper lobes of the lung, and its shadows will be found over the peripheral distribution of some of the upper lobe bronchi. The bronchial twig or branch involved may be small and the shadow correspondingly limited, or the area involved may be large, even an entire lobe; but the shadow will be a peripheral shadow and will be in the upper lobe, whether the tuberculosis is of the minimal degree, barely perceptible on the radiograph, or whether it is of the most extensive degree, involving all branches of both upper lobes. When tuberculosis spreads from the upper lobes into the lower areas, or when it invades the central or basal regions primarily, we may expect to find an accompanying or antecedent mixed infection, producing an atypical localization of the tuberculous lesions. There may be exceptions to this rule, but it forms the clinical basis of our interpretation of tuberculous shadows, and many observations have only strengthened our conviction that this is a safe working basis, in spite of exceptions which we have observed and which others, no doubt, can cite.

The interrelation between tuberculosis and syphilis has been in the minds of clinicians since tuberculosis was isolated from other lung diseases and established as a clinical entity. The effects of the acquirement of tuberculosis by a syphilitic person, and vice versa, have been discussed at length by many writers, but without definite conclusions, due, no doubt, to the uncertainty regarding syphilitic infection in the lung. Until there was a clear conception of lung syphilis itself, naturally no very definite idea regarding its combination with tuberculosis could be formed. Certain clinical observations which have served only to befog an already very puzzling condition are all that we have to date regarding a sinister combination which affects from 15 to 20 per cent of our great army of tuberculous patients. We have the conflicting statements that syphilis acquired by a tuberculous person will exert a favorable effect on the course of the tuberculosis; and, conversely, that it will cause a rapid extension of the tuberculosis. We also

Fig. 5 (Patient 3134). Extensive syphilitic infiltration of right base. Almost entirely resolved following two injections of salvarsan.

Fig. 6 (Patient 8675). Syphilitic sclerosis of lung and pleura. Wassermann positive. Autopsy showed complete destruction of lung tissue, with cicatrication, and large annular aneurysm of aortic arch.

have the confusing statements that a syphilitic who acquires tuberculosis will usually have an acute disease; and, conversely, that tuberculosis acquired by an old syphilitic behaves no differently from tuberculosis in a previously healthy person.

It is very apparent that here is a rich field for study. It is safe to assume that the previous observations on this double infection are not a safe guide, being necessarily based on an insufficient knowledge of the pathology of lung syphilis, and we can far better found our conclusions on our own investigations. Any such conclusions regarding a combination of syphilis and tuberculosis in the lung must give full consideration to the differences between an active, syphilitic inflammation, and the mild, slow fibrosis of old or latent syphilis.

Fig. 7 (Patient 11495). Diffuse and irregular densities in lungs accompanying syphilis of heart and aorta, probably due to active lung disease.

Tuberculosis and syphilis may occur simultaneously in the same lung, each producing its own lesions, which frequently can be distinguished on the radiograph. Since each of these shadows have been described, it is not necessary to dwell further on them.

The two diseases may also occur as a true symbiosis. This peculiar condition was first brought to the writer's attention by the publication of the researches of Dr. Carl Spengler,[15] of Davos, in whose papers we found an adequate explanation for the brilliant therapeutic results of Wright in treating tuberculosis with injections of mercury salts. The term symbiosis carries with it a tacit denial of the supposed antagonism between the organisms of tuberculosis and syphilis, for which there is no biological or clinical evidence. Symbiosis occurs when syphilis prepares the soil, either by active inflammatory destruction of lung tissue, or by a slow, mild inflammatory congestion. The localization of tubercle bacilli, thus influenced by syphilis, is more widespread, and we find the lesions and shadows not only in the upper lobes, but also in the bases. A symbiosis is also represented by the effects of acquired syphilis on a latent tuberculosis. Here, as Dieulafoy expresses it, the syphilitic virus "hatches the tubercle bacilli and sows them broadcast." A widespread distribution of tuberculosis may be produced by the latent, as well as the active form of syphilis. However, active syphilis, when grafted upon a preceding tuberculosis, results in a very malignant disease, which may not be true when tuberculosis is implanted in a lung where latent syphilis already exists. It is conceivable that a well established fibrotic tendency produced by a long-standing latent syphilis of the lungs, will choke out a tuberculous process when the latter occurs as a secondary infection. This, however, is tissue resistance and not bacterial antagonism, a distinction which is of vital importance in treatment.

A very similar symbiosis is found when tuberculosis and streptococcic infection exist in the same lung. A generalization of the tuberculosis results, because tubercle bacilli develop with greatly enhanced rapidity and vigor on a soil where streptococci have already grown. This fact, first demonstrated in the laboratory, has not been given proper consideration in studying the effects of "influenza" on tuberculosis. When we deny that influenza has any effect on tuberculosis

we are making a categorical statement that tuberculosis is not affected by any of the virulent pyogenic organisms which infest the respiratory tract, since these are all concerned, either primarily or secondarily, in influenzal infections. Now we do know that streptococci affect tuberculosis very markedly, and it is entirely possible that the cases studied by Fishberg[16] were pneumococcic infections, while those studied by other observers, with contrary conclusions, were streptococcic infections. However that may be, the streptococcic-tuberculous mixed infection will produce shadows very atypical for tuberculosis, and which cannot be distinguished, radiographically, from the shadows of tuberculous-syphilitic mixed infection. When we find typical shadows of tuberculosis and other shadows, usually of more recent formation, in atypical locations and without the familiar characteristics of tuberculosis, we may conclude that some additional and more malign agent than tuberculosis is at work in that lung. We cannot here, any more than we can in pure lung syphilis, draw positive conclusions from the shadows alone. However, these frequently are quite suggestive, and if our radiographic examination gives the right clue and leads to the ultimate formulation of a correct diagnosis, it certainly has done all that can reasonably be expected.

When we find pulmonary tuberculosis, with cavities which fill up with streptococcus infected pus, and, beneath these, the shadows of a disseminated tuberculosis, the conclusion should be obvious.

When the tuberculous process is under the influence of a symbiotic syphilis, the characteristics of neither infection will be preserved. Dieulafoy cites a case of a caseous gumma whose outer rind was thickly studded with tuberculomas about the size of peas; the shadow of such a lesion naturally would be very atypical. We may find areas where the typical tuberculous shadows are preserved; elsewhere there will be groups of small, rounded, or irregular densities, repre-

Fig. 8 (Patient 8133). Generalization of tuberculosis by streptococcic infection of the lungs.

Fig. 9 (Patient 8825). Healed tuberculosis of the lungs and pleura. Stereoscopically lesions shown to be partly in the lungs and partly on the pleura. History of pneumonia, with slow recovery extending over two years.

senting small consolidations without detectable relation to bronchial stems. Where the syphilitic areas have been invaded by tuberculosis, or where the encapsulated tubercle is broken down and the bacilli disseminated by the effects of syphilis, we cannot expect to find any typical arrangement of shadow. The absence of infected cavities, the confluence of small consolidations along the heart border, large hilus masses, diffuse fibrosis, should suggest syphilitic rather than pyogenic double infection.

Fig. 10 (Patient 8325). Tuberculosis and syphilis, shadows in the left lung resembling carcinoma, but proven by course of disease and effect of treatment to be syphilitic.

Fig. 11 (Patient 4668). Tuberculosis of upper right, with effusion in the base. Gummatous lesion of syphilis near left heart border. Entirely resolved under anti-luetic treatment, while the right sided lesions spread rapidly.

In the 6500 examinations previously mentioned, there were 948 patients who showed lesions of tuberculosis which had reached the advanced degree according to the classification of the National Tuberculosis Association. There were 192 cases whose radiographs had been disposed of and whose records were not clear enough to permit definite classification. In eleven patients there was acute tuberculosis, without radiographic evidence of a source of mixed infection to explain the generalization, and without history of antecedent acute respiratory disease. In 195 cases, the basal regions were practically free from abnormal shadow, the lesions being confined to the upper lobes, and these were considered to be essentially uncomplicated tuberculosis. In 550 patients the lesions had become disseminated into the lower lobes, and shadows were present which were atypical for tuberculosis and which could be explained only by some form of mixed infection. In 209, or over 22 per cent of the 948 patients with advanced tuberculosis, a diagnosis of combined syphilis and tuberculosis was made by us, or with our assistance. In the remaining 341 patients, a

Fig. 12 (Patient 9553). Combined tuberculosis and syphilis of the lungs, with aneurysm of the aortic arch.

simple diagnosis of tuberculosis plus some form of undetermined mixed infection was the conclusion from the radiographic shadows. This report includes only patients showing extensive shadows, and we have, doubtless, failed to recognize the true conditions in many patients with less advanced disease.

In closing this inadequate presentation of a very timely subject, it is well to emphasize its importance from a therapeutic standpoint.

First: In the treatment of systemic lues, it is important to know whether the lungs are involved, since a Herxheimer reaction in the lungs may be serious.

Second: It is doubly important, in tuberculosis, to ascertain whether the patient combats this comparatively benign single infection, or whether a sinister combination with active syphilis must be treated.

Third: It may be triply important not to disturb the fibrotic changes of latent syphilis by arsenical treatment, if the tendency of this fibrosis is to arrest the tuberculosis.

In all events, roentgenological examinations are indispensable, and the opportunities for scientific research and for practical benefit to medicine and humanity afforded us in the symbiotic infection, are not exceeded by any other lung disease.

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DISCUSSION

Mr. H. W. Dachtler. This paper has been of considerable interest to me as the work I did some years ago was on the secondary manifestations of syphilis, and of course my findings were entirely different. We found at that time, that the roentgen examination was practically negative. In other words, these cases had physical signs of an early tuberculosis, including slight temperature, but no roentgen signs that would verify that, and our conclusions were that it was a diffuse bronchitis in the secondary stage of syphilis, and where we found such cases with negative roentgen findings, we suspected lues. I have had, during my experience, three cases that are somewhat similar to some of the cases shown by the doctor, where there were discrete nodules. All of these cases had a history of syphilis, but we were never able to verify them by post-mortem examination.

I find it difficult to make clear that the findings we observed were not those of gumma. I have no cases in all my experience which I can identify as true syphilis of the lung. Those cases of secondary syphilis had antisyphilitic treatment, and they never developed any fibrosis, and for a very good reason—because the cases were early and they were cured, and the condition did not develop further.

Dr. Kennon Dunham. I know of nothing that is more important than the study of syphilis of the lung. We are getting, thanks to the *x*-ray man, more evidence every day which may some day help to substantiate a diagnosis of syphilis. I suppose there is not a large laboratory in the country that has not had definite lesions showing atypical densities which have cleared up under salvarsan. We have such plates in Cincinnati and we often treat them with salvarsan, but I hope, as roentgenologists, we shall not go on record as making a diagnosis of syphilis of the lung from these abnormal conditions. We can say that "such and such" a density suggests syphilis, but we cannot diagnose syphilis. The fact that a patient has a four-plus Wassermann does not mean that a given lung density is due to syphilis.

The specific organism of syphilis has not been demonstrated in the lung. Pathologists recognize two forms of pulmonary syphilis—

white pneumonia of the new born child, and gumma. Mr. Dachtler showed years ago that many cases which have physical signs of pulmonary tuberculosis but which have no roentgen findings of tuberculosis must be syphilitic, because they do not react to tuberculin and are cured by anti-syphilitic medication. Do not forget this important research of Mr. Dachtler. Even if we prove that certain abnormal densities within the lung are due to syphilis Dachtler has already proven that we may have pulmonary symptoms due to syphilis which do not give such abnormal changes.

Dr. Pritchard of Battle Creek, some time ago, showed me a series of slides in which lung densities had cleared up under salvarsan. I had similar plates in my own laboratory, and as I said before they are common in almost every large roentgen laboratory.

Let us remember that all these evidences of syphilis of the lung are not proof. Until the specific organism can be demonstrated in at least one such tumor we are not justified in doing more than suggesting pulmonary syphilis from our plates.

Dr. George W. Holmes. I have listened with a good deal of interest to Dr. Watkins' paper. We have had a few cases of lung syphilis which have been fairly well studied. The most interesting finding is a lesion in the bronchi causing a stenosis, and in some cases a complete collapse of the lung, producing complete dullness over the affected area The milder forms clear up under salvarsan when the bronchial stenosis is relieved. One advanced case came to autopsy. We could get no report from the pathologist except that "the patient may have had syphilis." We could not get him to say definitely that it was syphilis.

Dr. P. M. Hickey. I would like to ask the Doctor if he has any observations on syphilis of the pleura. I remember one case where I diagnosed tuberculosis with pleuritis, with a constant recurrent effusion, and the condition cleared up very quickly under salvarsan treatment.

Dr. W. W. Watkins (closing). I don't think I have anything particular to add, except to call attention to the fact that Mr. Dachtler stated in his cases there were no roentgen findings. In his original article, he mentioned in practically all of the cases that the bronchial markings were increased. This may or may not be similar to early syphilis changes.

I agree with Dr. Dunham thoroughly in the inadvisability of making the diagnoses from roentgenograms alone. My idea is to suggest syphilis as one of the things which produces the shadows which we see; never to make a positive diagnosis until the shadows have disappeared and the patient is well.

Answering Dr. Hickey's question, I have observed syphilis of the pleura in two cases, one where involvement of the pleura obscured the entire thorax on one side, where the probable diagnosis of syphilis was confirmed shortly after by autopsy. The other was a syphilitic pneumonia involving the pleura, in which the patient apparently recovered from the pneumonia, but the pleura always remained thickened.

ANEURYSM OF THE AORTA AND ABSCESS OF THE TRACHEOBRONCHIAL LYMPH GLANDS

By R. D. CARMAN, M.D. and C. G. SUTHERLAND, M.D.

Section on Roentgenology, Mayo Clinic

ROCHESTER, MINNESOTA

CASE 280177. Mrs. W. S., aged twenty-nine, wife of a farmer, was admitted to the Clinic July 15, 1919. Her health had been good until three months before admission. With the exception of abscessed teeth, several of which had been extracted about six weeks before, she had been in good health. The onset of her illness was gradual with a general tired feeling and some pain in the right side of the chest and around the heart. Her symptoms were attributed to overwork, but rest and later one week in a hospital failed to improve her condition. Within two weeks of the extraction of her teeth her temperature rose in the evening, reaching an average of 99 degrees; her pulse was rapid, and her breath short on exertion or when she was lying on her back. She choked at times when taking food. Half an hour after eating she had coughing spells in which she raised large amounts of clear sputum. Later a wheezing in the throat of gradually increasing severity was noted. She lost seven or eight pounds in weight during her illness.

Examination revealed slight bubbling râles over the chest. The heart was not enlarged; a systolic murmur was heard only at intervals; the pulse was rapid and irregular. The abdomen and pelvis were negative. The systolic blood pressure was 120, the diastolic was 80, the pulse was 100, and the temperature 99.5°. Examination of the blood was not recorded. The Wassermann reaction was negative.

Roentgen examination revealed a mass bulging into the upper mediastinum which with the fluoroscope proved to be non-expansile but was thought to be an aneurysm of the arch of the aorta.

The patient died four days after admission to the Clinic; the necropsy findings were as follows:

A large spherical, encapsulated, non-tuberculous abscess of the tracheobronchial lymph nodes (from 10 cm. to 12 cm. in diameter) was found. This mass, situated at the bifurcation of the bronchi, rested behind the bronchi, more to the left side, in front of the esophagus, and against the right pulmonary artery and vein and the descending arch of the aorta. There was evidence of extensive compression of the trachea and of the esophagus. The bronchial tree was filled with unexpectorated mucus and the entire venous circuit was markedly engorged. The body was strikingly livid and showed moderate emaciation with some edema.

CASE 8734. Mr. G. R., aged fifty, a bartender for a time and later a stationary engineer, was admitted to the Clinic August 28, 1919, complaining of a dull pain in the left chest. This pain was not influenced by respiration, but was accentuated by coughing or sneezing. He had had left side pleurisy with effusion five years before and five attacks of pleurisy in the intervening period. He had left side pneumonia in 1918 and in 1919 was confined to bed for several days with "chest trouble." At this time he had a tickling sensation extending down the left bronchus, followed by a slight cough and a small amount of whitish expectoration. In 1908 the patient had been treated at the Clinic for urethral stricture; he had had chancre at the age of twenty-seven and a history of gonorrheal infection over ten years. He complained of shortness of breath, weakness, aching between the shoulders at night, occasional night sweats, and that he was incapacitated for work. He had lost twenty pounds in weight in six months.

Examination revealed general adenopathy, expansion was limited on the left side of the chest; the percussion note was flat; vocal resonance and vocal fremitus were diminished. The breath sounds on the left side were distant; there were no râles, and no changeable dullness. The pulse was regular; a systolic murmur heard at the base and to the left of the mid-sternal line was believed to be an accentuated second sound. The systolic blood pressure was 136, the diastolic 92; the hemoglobin and blood count were normal. Examination of the sputum, the Wassermann reaction, and the electrocardiographic findings were negative.

Roentgen examination revealed a dense shadow throughout the entire area of the left lung. This suggested fluid, but aspiration failed to reveal it. An attempt to elicit fluid two days later by the same method failed and a small incision was made, deep enough to allow a few tiny bubbles of air to escape. The pleura was not appreciably thickened but appeared to be adherent to the lung. Pneumothorax did not follow these operative procedures.

The patient returned to his home September 2, and word was received of his death in November.

We are indebted for the following notes to Dr. T. R. Martin, of the Duluth Clinic, who performed the necropsy:

"On opening the chest both pleural cavities were found to be obliterated by old adhesions and the pericardium was adherent to the pleura on the left side. The lungs and heart were removed *en masse;* in stripping down the descending aorta the knife met with an obstruction, which proved to be an aneurysm of the first portion of the descending aorta, about 9 cm. by 10 cm., containing an organized clot. The posterior wall of the aneurysm was firmly adherent to the spine and had produced pressure necrosis on the lateral aspect of three of the dorsal vertebrae.

"There were no abnormalities of the heart or pericardium except calcareous deposits

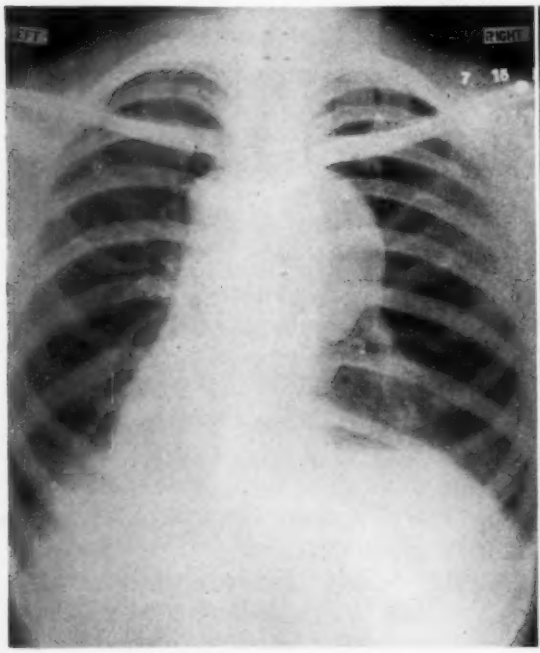


Fig. 1. Case 280,177. Shows shadow bulging into upper mediastinum.

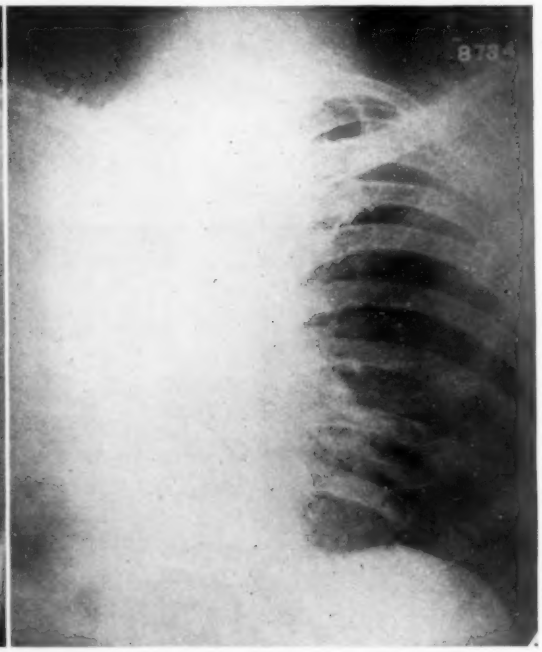


Fig 2. Case 8734. Shows dense shadow in area of left lung.

at the bases of the cusps. The aorta showed numerous calcareous plaques at the site of the aneurysm. On introducing the finger through the auricle into the pulmonary vein an obstruction was met which suggested an acute angulation of the vein from pressure and distortion by the adherent aneurysm. The pulmonary artery on the left side was patent.

"The left lung was dark red, glistening, and moist; on section it was firm and liver-like in consistency and contained no air.

"There was nowhere any evidence of tumor formation.

"A roentgenogram was made of the heart and left lung removed from the body and in this the left lung cast a shadow more dense than the heart free from blood suggesting that the antemortem shadow in the left lung was due to passive congestion."

In Case 280177 the plates and fluoroscopic examination revealed a non-pulsating shadow bulging into the upper mediastinum, which could not be distinguished from the arch of the aorta (Fig. 1). In spite of the patient's age, a negative Wassermann reaction, and the fact that the shadow was non-expansile, aneurysm, in our opinion, was the logical diagnosis. In the literature it is generally agreed that aneurysm rarely occurs without a coexistent history of syphilis; on the other hand, it is known that patients may acquire syphilis unknowingly and that the Wassermann reaction may be negative in the presence of syphilitic infection. No expansile pulsation was observed in the shadow in this case, but it is not always present in aneurysm of the arch of the aorta.

In Case 8734 the roentgen findings were definitely those of fluid in the pleural cavity (Fig. 2). The course of the aorta could not be defined because of the extent and density of the shadow. The clinical findings were as characteristic of fluid as were the roentgen findings and the history of repeated attacks of pleurisy and a left side pneumonia was definitely misleading.

In corresponding with Dr. E. L. Tuohy of the Duluth Clinic we learned that because of the patient's history of syphilis he had earlier in the summer been given rather intensive treatment for syphilis without any apparent improvement in his condition.

A noteworthy feature of these two cases was that the Wassermann reaction was negative in both, although in the second there was a definite history of syphilitic infection.

These two cases are of interest because the roentgen findings were considered characteristic enough to allow of a definite diagnosis, yet necropsies proved them to be incorrect.

PELVIMETRY BY MEANS OF THE ROENTGEN RAY*

By W. EDWARD CHAMBERLAIN, M.D.
Assistant Professor of Medicine, Stanford University
AND
R. R. NEWELL, M.D.
Assistant Roentgenologist, Stanford University Hospital,
SAN FRANCISCO, CALIFORNIA

BY the use of films and double screens, it has recently become possible to get clear pictures of the maternal pelvis and the fetal skeleton at full term. This seemed to us to reopen the question of roentgenographic pelvimetry.

Martius[1] has given a very complete review of the literature on the subject up to 1914. After the first simple comparisons of roentgenograms of the patient with those of dried abnormal pelves, various mechanical and mathematical methods were developed to correct for parallax and foreshortening. The mechanical method culminated in the very complicated and expensive chair designed by Kehrer and Dessauer[2], which reconstructed by threads in space the straight lines connecting target, object and plate image and measured between their intersections. Martius found their method accurate enough, but they themselves were unable to get plates clear enough to measure after the first few months of pregnancy. The mathematical method culminated with that of Runge and Gruenhagen[3] in 1915, which is both simple and accurate. The only special apparatus used is a plate tunnel and a plumb-bob. They availed themselves of the stereoscope to identify the points from which to measure on the plate, a refinement first used by Manges[4] in 1912. It is a simplification of this method that we are offering.

In using films, it seemed desirable not to use the edges to orient them by, as Runge and Gruenhagen had done with plates, so we have had a plumb-bob impress its shadow on each exposure. We have discovered a simple construction for the horizontal projection of the desired diameter, which is even easier than the perpendicular from which Runge and Gruenhagen measured, and in addition simplifies the final calculation.

THE APPARATUS

We are using a tube-stand and table of standard make, the double screen cassettes being carried on the plate changer provided in the table. Across the celluloid window, somewhat above the middle, is stretched a wire (about 20 gauge). In the center of the 1 mm. aluminum filter is a very small lead ring, from which hangs on a cotton string a plumb-bob, consisting of a rod 3 by 50 mm., with two rods 1 by 30 mm. set through it near the end at right angles to its long axis and to each other.

METHOD OF TAKING THE PICTURES

The target is set 88 cm. above the plane of the film. We have chosen this target distance arbitrarily. The shadow of the plumb-bob is observed on a bare screen, and the tube holder is tilted until the shadows of plumb-bob and lead ring are concentric, thus bringing the plumb-bob vertically below the target. The patient is made to lie down on the table, with her pelvis over the celluloid window, a lead marker is placed under her right hip, the tube is brought over the right iliac region and an exposure made. The tube is shifted 10 cm. to the left parallel to the wire above mentioned, and another film exposed. It is necessary that the exposures be full, for an under exposure will fail to show the shadow of the plumb-bob, and the promontory of the sacrum will probably be obscured by the density of the fetal head. With a radiator

* Read at the Winter Meeting of the Pacific Coast Roentgen Ray Society, and the Western Section of THE AMERICAN ROENTGEN RAY SOCIETY, San Francisco, California, December 10, 1920.

Coolidge tube about 15 sec. at 30 ma. at a 4 inch gap has given readable pictures.

MEASURING THE FILMS

The films when dry are placed in the stereoscope, or are viewed on the light box with a prism hand stereoscope, and the points marked between which measurement is desired, e. g., the promontory and symphysis, the ischial spines, the brim at sacro-iliac joint and ileopectineal eminence, etc. Then on the light box a piece of clear celluloid is laid over one of the films, and on it marked (1) two dashes over the shadow of the wire, (2) the center of the plumb-bob, and (3) the points on the pelvis, labeling each pair. The celluloid is then laid over the other film, setting the dashes over the shadow of the wire, and the mark for the plumb-bob exactly 10 cm. from the second plumb-bob shadow. The points on the pelvis are then marked in their new positions. Draw lines connecting the plumb-bob dots with the pelvis dots belonging to each, and another connecting the intersections. The tracing for measuring, say, the conjugata vera, will then appear thus (see Fig. 1).

A centimeter scale laid on y gives the length in centimeters of the horizontal projection of the required diameter. A special scale laid on a and b gives the height in centimeters of each end of the conjugate above the plane of the film. The length of the conjugate is then computed from the formula:

$$x = \sqrt{y^2 + (a-b)^2}$$

ACCURACY

As a check on the method we have used a light wire 10 cm. long with spherical knobs on the ends. This is laid across the symphysis when the exposures are made. If calculation from the films gives the length of this correctly, then one may be sure that no mistakes were made, and can trust the calculations for the other measurements. Accuracy in determination of the pelvic diameters will depend almost entirely on the accuracy with which the points are marked on the films. That this is a real cause of error was shown by determinations on dried pelves, where the results at times differed from the calipered lengths of the antero-posterior diameters by as much as 4 mm. This I believe was due to the difficulty of marking accurately the posterior

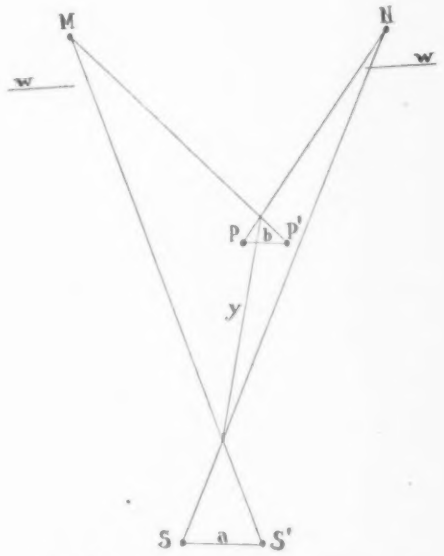


Fig. 1. Tracing ready for measurement. M and N are the plumb-bob marks. w and w mark the wire, P and P′ the promontory, and S and S′ the symphysis.

surface of the symphysis. The promontory of the sacrum is also, to a less degree, a source of uncertainty. The oblique diameters of the inlet and that between the ischial spines are, however, always very definite, and these are not only of prime importance in the mechanism of labor but are most unsatisfactorily estimated by the classical methods of pelvimetry. Error here has been less than 2 mm.

It should be pointed out that the method we have described is more widely useful than merely for pelvimetry. It can be used for measuring almost any of the dimensions of the skeleton, and perhaps even of soft parts. By taking a third exposure to rule out movement, the dimensions of the fetus may be estimated.

We wish to thank Dr. A. B. Spalding for the interest he has taken in this problem and for the use of clinical material from the obstetrical service of Lane Hospital.

For completeness the mathematical treatment of the problem is given below, but an understanding of it is not necessary in the actual use of the method.

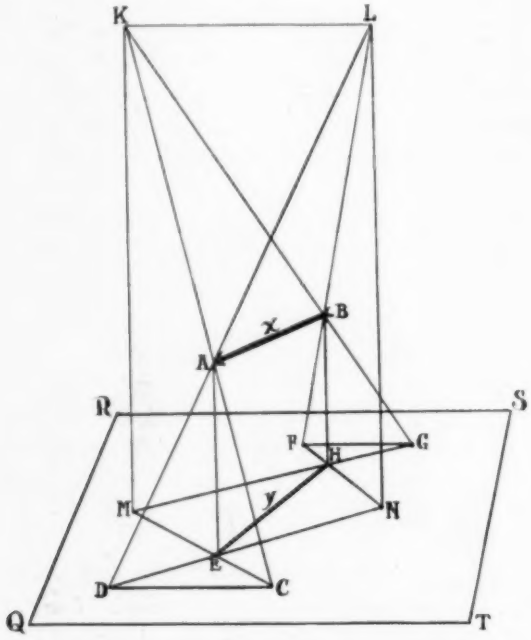
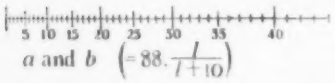


Figure 2.



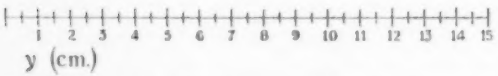


Fig. 3. Special Scale for Measuring the Tracing.

The unknown points A and B are projected onto the horizontal plane QRST from the two positions of the target at K and L, showing as the points D. C. F and G. M and N are the plumb-bob shadows and lie vertically below K and L respectively. (Fig. 2.)

Since in the triangles KMC and LND, KM and LN are vertical, MC lies vertically under KC, and ND under LD. Therefore E, the intersection of MC and ND, is vertically under A, the intersection of KC and LD; i.e., AE is vertical.

Similarly BH is vertical.

Since HE is horizontal, the figure ABHE is a right trapezoid. Its hypothenuse, AB, is the length to be measured.

$$\therefore (AB)^2 = (EH)^2 + (AE - BH)^2$$

EH is y in Figure 1 and directly measurable; and AB is the unknown length x.

$$\therefore x^2 = y^2 + (AE - BH)^2$$

$$x = \sqrt{y^2 + (AE - BH)^2}$$

Since KL is parallel to QRST, KL, DC and FG are all parallel.

$$\therefore \frac{KL}{DC} = \frac{KA}{AC}$$

$$\frac{KL + DC}{DC} = \frac{KA + AC}{AC} = \frac{KC}{AC}$$

$$\text{But } \frac{KC}{AC} = \frac{KM}{AE}$$

$$\therefore \frac{KM}{AE} = \frac{KL + DC}{DC}$$

$$AE = KM. \frac{DC}{KL + DC}$$

$$\text{Similarly } BH = LN. \frac{FG}{KL + FG}$$

We have chosen KM and LN = 88 cm. and KL = 10 cm.

$$\therefore AE = 88. \frac{DC}{DC + 10}$$

$$\text{and } BH = 88. \frac{FG}{FG + 10}$$

If, now, we construct a scale on which a length of 1 cm. reads $88. \frac{1}{1 + 10}$, we can by applying it to DC and FG, read off directly the magnitudes of AE and BH respectively. Let us call these readings a and b, then the formula becomes:

$$x = \sqrt{y^2 + (a - b)^2}$$

For convenience we have printed on a piece of celluloid a centimeter scale for reading y as well as the special scale for reading a and b. (See Fig. 3.)

SUMMARY

A simple method is described for measuring bony dimensions, notably of the female pelvis, by means of roentgen rays. The special apparatus required comprises: 1. a cross-arm plumb-bob. 2. An aluminum filter with small lead ring from which to hang the bob. 3. A light bar of known length for an automatic check on the accuracy of the exposure-making. 4. A special scale to lessen the burden of the calculations. (See Fig. 5.)

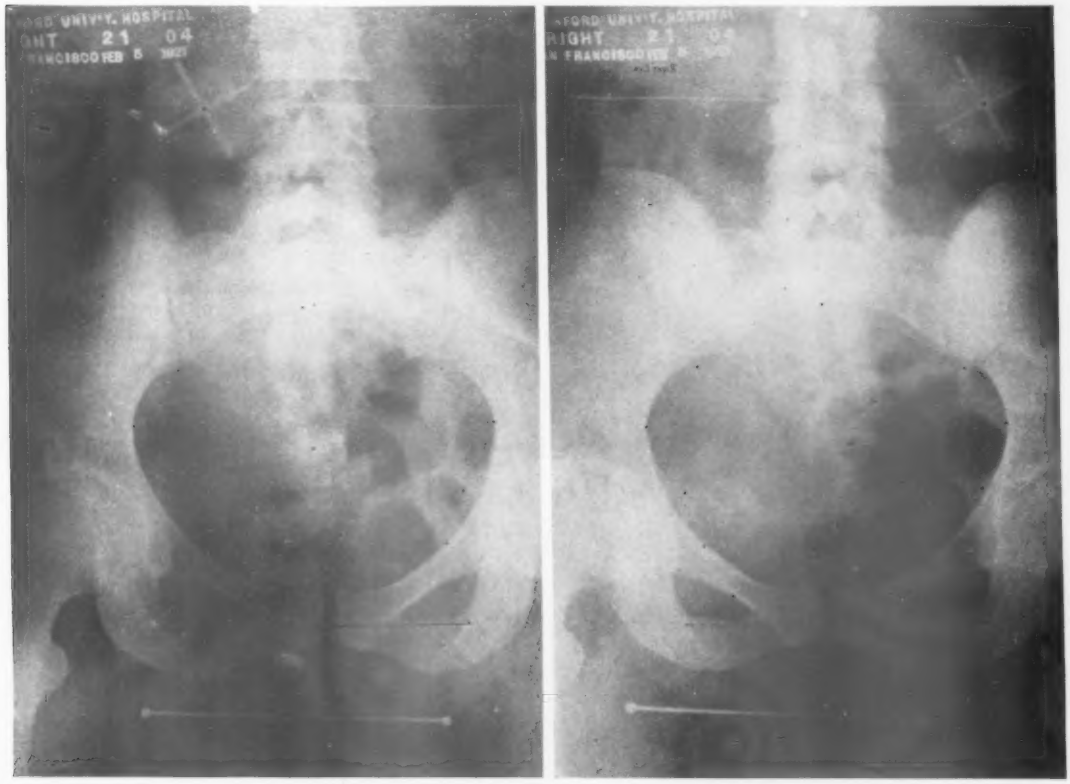


FIG. 4. The two films marked and ready for tracing. Dots have been put at the ends of all the principal pelvic diameters (internal). The line drawn between the ischial tuberosities is for the measurement of the anterior and posterior sagittal diameters. (The films taken at term show hardly enough contrast for satisfactory reproduction.)

The following are the measurements of this pelvis.

Pelvic inlet:	Anteroposterior	$\sqrt{9.5^2 + 6^2} = 11.2$ cm.
	Transverse	$\sqrt{13.3^2 + 1.5^2} = 13.4$ cm.
	Right oblique	$\sqrt{10.9^2 + 5^2} = 12.0$ cm.
	Left oblique	$\sqrt{10.8^2 + 7^2} = 12.8$ cm.
Plane of least dimensions:	Anteroposterior	$\sqrt{4.7^2 + 9^2} = 10.1$ cm.
	Transverse	$\sqrt{11.2^2 + 1.5^2} = 11.3$ cm.
Pelvic outlet:	Anteroposterior	$\sqrt{2.1^2 + 6.5^2} = 6.8$ cm.
	Bisischial	$\sqrt{11.7^2 + 0} = 11.7$ cm.
	Anterior sagittal	$\sqrt{1.1^2 + 4^2} = 4.1$ cm.
	Posterior sagittal	$\sqrt{5.8^2 + 6^2} = 8.3$ cm.

(Caesarian section was done for threatened eclampsia and at operation the true conjugate was measured and found to be 11 cm., a discrepancy of 2 mm.)

[NOTE: Since sending this in for publication we have acquired a Potter-Bucky diaphragm.

Fig. 5. Filter, Plumb-bob and Control Rod.

We find that the negatives of the pelvis taken with this are very much clearer, and consequently capable of much more accurate measurement.

We are using a universal Coolidge tube at 9 inch parallel spark-gap at about 15 milliamperes, and find that fifteen seconds is a satisfactory exposure for moderate size pregnant abdomens.]

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PRESENT PROBLEMS AND FUTURE PROSPECTS OF DEEP ROENTGEN THERAPY*

BY ALBERT SOILAND, M.D., F.A.C.P.

LOS ANGELES, CALIFORNIA

WITHIN the past year, one of America's distinguished physicists inquired of the writer whether the roentgen ray had any therapeutic action on tissues other than the skin. This question, propounded in all seriousness by an acknowledged expert in *x*-ray physics, if accepted as indicative of a general lack of knowledge of this work, reflects rather discreditably upon those of us who have been endeavoring to set forth the doctrine of deep roentgen therapy. We have failed either to present tangible facts in convincing form through the medical press, or we have written too much at random and with so apparent a lack of unanimity of opinion as to disqualify our claims.

For some reason, *x*-ray therapy has not kept abreast of diagnosis, and unless we arrive at a certain stage of unification and standardization of the former our efforts will not bear the fruit they should. With this purpose in mind, a brief survey of some phases of this work may be of value. Since it is generally admitted that in certain limited diseases of the skin and appendages, the *x*-ray is an undisputed dominating factor, we shall confine our attention in this discussion to the present day accomplishment of so-called deep roentgen therapy. We shall also touch on what are, in our opinion, the most vital of the problems facing the *x*-ray operator to-day.

In the comparatively recent period in which short wave lengths of *x*-radiation have been produced in working quantities, a mass of valuable therapeutic data has been accumulated. With this as a basis, we can segregate the conditions in which favorable results may be expected, conditions which will uniformly show an end result varying

*Read at the Twenty-first Annual Meeting of THE AMERICAN ROENTGEN RAY SOCIETY, Minneapolis, Minn., Sept. 14-17, 1920.

between more or less permanent relief and a clinical cure. As falling within this class, we may roughly enumerate certain glandular and organic diseases. Named in the order of their responsiveness, we would mention localized adenopathies, simple post-infectious, and tubercular. From this list, we are excluding luetic and carcinomatous glands. Next in order are diseases of metabolism due to hypo- and hyper-secretion, those involving the thyroid, thymus, adrenals, and, according to more recent investigations, the pituitary. Hyper-activity of the ovary is very readily influenced and corrected by deep roentgen therapy. The same influence can easily be obtained upon uterine cells, particularly where menorrhagia is a sequence. Fibromata and myomata show a uniformly favorable response in a manner to convince the most skeptical. In the spleen and its associated leukemias we have a stay of the pathological blood changes sufficient to make the effort distinctly worth while. The list of conditions enumerated may be said roughly to include the present day indications for deep roentgen therapy in so far as clinical relief may be expected, and for which up to the present time no other more useful medical agent has been found.

The question will of course be raised: In the malignant forms of internal disease, has the *x*-ray any action which will warrant its use? From a careful perusal of the literature, and a knowledge of the work of many conscientious radiologists, as well as from our own experience, which has extended over a period of many years, we have reached the conclusion that in certain types of internal malignancies roentgen therapy has achieved some success. This is particularly true in carcinomatous glands. Those due to an extension of a malignant process respond more favorably than those due to a true metastasis. Our failure to influence carcinomatous masses has been largely due to our inability to deliver to any particular deep area a lethal dose. This is a problem which the future must solve. There are on record, however, a considerable number of cases of sarcoma, of which we have had several in our own practice, that have been clinically cured by deep roentgen therapy.

As is well known, in carcinoma of the deep tissues, we have had very little encouragement; yet the following case is so extraordinary that it is well worth recording. The patient, male, forty-two years old, with carcinoma involving the lower third of the stomach and the pylorus, inspected through abdominal incision, was declared inoperable and also pronounced malignant by every laboratory and clinical test. He had the usual signs of advanced pathology, pain, cachexia, and rapid loss of weight, and was referred for roentgen treatment as a placebo. The upper abdomen was subjected to intense *x*-ray exposures with heavy filters. In sixty days, the patient had gained twenty pounds, his color was better, his appetite and stomach function greatly improved. *X*-ray treatment has been continued for several months. Nearly a year has elapsed since the exploratory incision. At present, the tumor is no longer palpable, but the tissues on deep pressure feel fibroid and non-elastic. The patient's stomach functionates properly, he retains his normal weight, feels well, and maintains active work. The outlook is decidedly hopeful.

The present day problems of deep roentgen therapy have to deal largely with our ability to deliver a sufficient number of radio-active units to the tissues we wish to influence. With the instruments now available this is acomplished to a certain degree, but we are yet far removed from an ideal which will permit us to deliver at will a known quantity of the energy of radiation to a desired point. In deep roentgen therapy, our first aim is to deliver to the part sufficient radiation profoundly to influence this part, not, as is often the case, merely to a point of stimulation or irritation, but in sufficient force to cause a complete inhibition of pathological cell activity. From a theoretical stand-point, it would seem logical to assume that when a bundle of deeply acting rays pass through cellular tissues of widely differ-

ent construction and function, both normal and pathological, if such rays are delivered in quantity sufficient to inhibit the action of the pathological cells, the normal structures must suffer equally. Undoubtedly this is true to a degree, yet there is very little evidence that such destruction actually occurs. It must be remembered that we are not referring in these remarks to the European 16-hour technique or to *x*-ray necrosis with secondary destruction due to so-called burns associated with the skin and adjacent tissues. The writer has always assumed that in the soft cellular tissues of the body very little absorption of rays occurs, and that only in congested areas with cellular impaction are the rays absorbed sufficiently to give off the well-known secondary effects, which are the actual working units of ray energy. If this simple hypothesis is accepted it would easily explain why we get an apparent selective action on pathologic structures.

In our work, one of the most important of the problems is the thorough and effectual protection of the skin and its appendages. There is a healthy endeavor in this direction now evident, and our former two or three millimeters of aluminum are now replaced by six to ten millimeters of aluminum. This is highly desirable when working with one hundred kilovolts or more. Another phase of the same problem is the protection of the operator as well as of the patient. Under such high tension work, the patient is frequently better protected than the operator. The usual protective screens, which come as a part of the generating plant, are wholly inadequate. Lead one-half inch thick on three sides of the operator's booth is none too heavy. The lead glass windows in such a cabinet should be in layers to make a one inch thickness. It is doubtful whether any of us take this amount of precaution, but it is most certainly indicated.

Radiologists to-day have a fairly definite idea of what constitutes a safe massive dose, yet there is so great a difference in the technique of the various operators that a definite general formula cannot be adopted. A massive dose through ten millimeters of aluminum filter has an entirely different range of activity from one where four millimeters are employed with the same setting. Again, one using an eight inch focal distance and another ten, with otherwise the same formula, will fall far short of arriving at the same point. The greatest difference in the formulae, however, is in the kilovoltage constant. It is extremely difficult to maintain a consistent ten inch back-up with our present equipment, although this point should be striven for if we are to expect definite effects deep down in the tissues.

Gleanings from the field make it apparent that the average massive deep dose ranges in formulae as follows: Voltage or spark back-up equivalent from 7½ to 10 inches, focal distance 6 to 10 inches, filters 3 to 6 millimeters aluminum, milliamperes on tube circuit 4 to 6, time 5 to 10 minutes. From these various combinations, a very effective deep massive dose could be administered, and on the other hand one of no practical use whatever could also be chosen. In an attempt at standardization, the writer is now engaged in working on formulae based upon the distance beneath the surface we endeavor to reach. Briefly these are as follows: With 3 constants, back-up 10 inches, focal distance 8 inches, milliamperes 5, tissues up to 2 inches below the surface, 4 millimeters aluminum filter, time 7 minutes. This dose may be repeated twice within thirty days over the same skin area. Tissues 4 inches below the surface, 6 millimeters aluminum, time 10 minutes. This may be repeated over the same area twice up to thirty days. Parts 6 inches or more beneath skin, 10 millimeters aluminum, 15 minutes time. This dose may be repeated three times in thirty days. In all this work, an additional cotton filter, one-half inch thick, under compression, is employed. No further exposure is permitted over the same surface within three months.

The future prospects of deep therapy are distinctly encouraging. When we look back upon the comparatively few years in which

an effort has been made to separate the wheat from the chaff in *x*-ray therapy, we have strong reasons to be optimistic. No doubt certain improvements in apparatus will soon be developed: First, an electrical generator with unlimited voltage, so constructed as to render the patient's circuit free from danger; second, a controlling device calibrated with a selective system to give any range of penetrability desired; and third, a "Coolidge" tube of sufficient capacity to lend itself in every way to the requirements laid down. If such a development occurs in the not too distant future, the scope and success of deep roentgen therapy will be materially increased. Will such evolution of *x*-ray energy prove a definite cure for cancer? The writer believes not, but he also believes that it will be found in that case to be superior to surgery, and, combined with the latter, will probably be the best method of attack, until the true cause of this terrible disease of modern civilization has been found and conquered.

Addendum: Since this article was written, I am informed that American engineers are perfecting high voltage tubes and transformers of even greater capacity than those in foreign service, and that these will soon be available for our use. This eventuality, of course, will necessitate a complete reorganization of all our present treatment factors.

THE AUTHOR.

GENERAL DISCUSSION FOLLOWING SYMPOSIUM ON THERAPY

DR. G. E. PFAHLER. There has been so much material presented in these papers that it is impossible to discuss everything thoroughly. The work presented by Dr. Levin was of a fundamental character, and will give us principles to work on that do not need so much discussion.

The excellent results obtained by Dr. Hickey in the treatment of papillomata and carcinomata of the larynx are brilliant. You can get, however, good results, too, by the external application of radium or *x*-ray. I have had a patient with carcinoma of the larynx for approximately six years, treated by the *x*-ray alone, cross-firing as much as possible on the disease. I have used the intubation tube, adapted according to the case, for the introduction of the radium inside. The method Dr. Hickey has used of bringing the capsule up from below in the tracheotomy wound is very good. I had thought of doing that, but have never done it. I have a patient at the present time with a tracheotomy wound, and I may carry out that technique when I get home.

I was very much interested in the needle technique described by Dr. Boggs, and I am just as enthusiastic in that as he. I believe that by properly combining the radium with the *x*-ray, we can get more carcinomas of the breast well than by any other means or any other combination. I had a little experience with one case that has been to me most striking, and this patient seemed to be hopeless, even for radiumtherapy, when I started. The patient had been operated on a year before for carcinoma of the right breast. The patient was sent to me with an ulcerating recurrence in the scar, approximately two inches in diameter, with indurated extensions along the scar, and a nodule in the axilla of the operated side, perhaps an inch in diameter. The unoperated breast contained a tumor mass, a group of nodules extending up into the axilla, varying from a half inch to an inch. There was present, also, mediastinal infiltration, presumably carcinoma, extending outward into the lung area. You will admit that is a pretty bad picture. There were also numerous nodules in the supraclavicular region on the left side, which was the side not operated.

I introduced radium needles directly into the carcinoma of the breast and each of the nodules leading up into the axilla, and into the recurrent nodules in the opposite axilla. I made surface application of radium to the

nodules in the supraclavicular region, and I made surface application of the radium over the recurrence in the scar. Then I cross-fired with the *x*-ray into the mediastinum through numerous portals of entry. That was started in February. So far as we can see to-day, either by eye, by finger or by roentgenogram, that disease has disappeared. That is more of a result than I believed could have been obtained by a combination of *x*-ray and surgery.

I have used radium needles in some other cases of carcinoma of the breast, but they were of a kind that might have gotten well by other means. I believe this case probably would not have recovered, although I have had some striking results even with the *x*-ray alone, but I am convinced that where you can bring the radium in direct contact with the part, either by direct surface application over a nodule or by introduction of the needle into the disease, you get more pronounced and startling results than by *x*-ray application. It may be because we are using more secondary rays that we get the more pronounced results. However, for the treatment of general surface, or for treatment into the mediastinum, you will get better results by the roentgen rays.

Dr. Kennon Dunham. I should like to ask Dr. Pfahler what are the sizes of the areas of cross-firing in the mediastinum. How large an area can be treated with the *x*-ray?

Dr. G. E. Pfahler (Answering Dr. Dunham). About three inches square. I would like to add a word about cross-firing. I see a great deal of marking up of the chest and cross-firing. Unless you can make that portal of entry bring about an actual cross-fire, you might as well treat two, three or four areas at a time. You must decide, first of all, as near as you can, where your tumor is, and then all your rays should be passed through that tumor area. You ought to arrange the position of your tube, etc., so that your rays go through the tumor. The doctor can do better *x*-ray therapy than the technician, because he is supposed to know anatomy and he is supposed to know pathology, and he is supposed to know where the disease is, etc. It should be his business in each instance to direct his treatment toward that disease.

Dr. George C. Johnston. The statement Dr. Pfahler has just made in regard to cross-firing and the necessity of aiming accurately in the direction of the tumor is, of course, correct, but I would take considerable issue with the statement that radiation directed toward a solid body, such as a patient, even if not directed in the proper axis, would have no effect. It has been well established, I believe, that all the therapeutic effect you get from *x*-ray radiation is due to secondary radiation in the tissue, so it wouldn't make so very much difference if the rays were directed absolutely or not in the proper mathematical direction. I have never been able to convince myself that the filtered gamma rays from radium were directly able to do very much. It is in all probability the secondary radiation set up which has the effect, and the same is true of the highly penetrating *x*-rays. Why do we get so much more effect when we use a highly filtered *x*-radiation with correspondingly less length of application? It may be that it is due to the secondary radiation.

Now, we know that the very radiation that is therapeutically effective is radiographically outlawed. We know that the secondary rays will produce a foggy plate, but these are the rays which are therapeutically effective. Did you ever think about that?

Dr. W. C. Alvarez. I would like to call attention at this point to some ideas again from those worms I talked about yesterday. To my mind, some of the most stimulating work done on the cancer problem has been done by a zoologist, Professor Child. If you wish to get a new outlook on the cancer problem, I would suggest that you read his book on "Senescence and Rejuvenescence" published by the University of Chicago in 1915. There he shows how the original embryonic cells are undifferentiated, that is, they are all about alike and all have the capacity for rapid growth. Later, as they differentiate and take on special functions, they fill up with material which he calls metaplasm. This more or less fixed and dead material increases in amount as the cells grow older; and with its increase, they lose their original power of growth and multiplication.

Finally, a time comes when the cell develops the power of eating up the metaplasm, it de-differentiates, and in so doing regains its original power of rapid growth and fission.

This method of rejuvenescence is naturally of great value to lower organisms, but it constitutes a great menace to the higher animals. I believe that a careful study of this mechanism in the lower organisms may help us greatly in finding the cause and cure of cancer.

The idea of a metabolic gradient comes in in the treatment of cancer. The rapidly growing tumor cells probably have a fast metabolic rate and a large demand for oxygen. We have seen that such rapidly growing tissues suffer more from some poisons than do tissues of slow growth; and the problem of cancer cure, as I see it, is to find some substance which will damage the rapidly growing cells and leave intact the more slowly growing ones of the host. In working towards this end, it would be very helpful to know exactly what the rates of metabolism are in the different parts of the body and in the tumors.

Some of you have asked me for suggestions as to the causes of nausea after roentgen ray treatments. I will say that in the Hooper Foundation, my chief, Dr. Whipple, and some of his associates have been giving large dosages over the abdomens of dogs, and they have found that they can produce deep ulcers in the mucous membrane of the stomach and intestine. If the cone used is a small one the ulcers are small and their edges are sharply limited. If such lesions are produced in man they may account for some of the digestive upsets seen after roentgen ray treatment.

Dr. W. S. Lawrence. I would like to hear a little discussion on the matter of equivalent filtration. This is what brought the thought to my mind. Someone in a paper yesterday said he was using one millimeter of copper and that one millimeter of copper was equivalent to 19 mm. of aluminum. Now if that is true, I would like to know it. Roentgen, in his original paper, stated that the *x*-ray penetrates all materials in proportion to their specific gravity. I do not know that that law has ever been proven false. Now copper is only about three times as heavy as aluminum, and three or four millimeters of aluminum ought to be equivalent to one millimeter of copper.

One other point I would like to suggest: In treating a widespread involvement like the case Dr. Pfahler mentioned, of carcinoma involving practically the whole thorax, and particularly where the lungs are involved, I think the distance method over a large area is a much more valuable method of application than the method of blocking off in small areas, because, as Dr. Pfahler said, in small areas improperly directed, the part below will not get the required amount. Although there is a difference of rays which gives you some cross-fire, even though you direct the central rays at right angles, still the part below the center of one of those areas would get only about what the skin would stand at six or eight inches, according to the distance you select. But if you get twenty inches from the part, and hit a large area, then the part below will get nearly as much as the skin and the effect will be much greater and incidentally you save a great deal of time.

Dr. A. L. Gray. I didn't hear all of Dr. Hickey's paper, but many of the members will recall that at the meeting in Niagara, I reported four cases of laryngeal papillomata treated by the *x*-ray with almost complete success in all four of them. I have since added two adult cases. I would like to know from Dr. Hickey how long he treated this case, and how long he waited after the treatment? My experience with cross-fire radiation in laryngeal papillomata, non-malignant, has been very satisfactory.

Dr. P. M. Hickey. In reply to Dr. Gray's statement, I will state that I waited between three and four years. She had treatments extending over three months, and was also treated elsewhere by the *x*-ray. I tried to bring out in the paper that, from a clinical standpoint, there are two kinds of laryngeal papillomata, one of which is very amenable to surgical treatment, and the treatment I suggested is simply for those intractable cases of papillomata of the larynx. A certain number are very amenable to surgical treatment, and evidently, from the Doctor's remark, to roentgen treatment, also. There is, however, another class which tends to recur very persistently and it is in that class I suggested the contact application of radium to the papillomatous masses.

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Information of interest to all readers and lists of officers of The American Roentgen Ray Society and The American Radium Society will be found on the two pages preceding Table of Contents.

TWENTY-SECOND ANNUAL MEETING THE AMERICAN ROENTGEN RAY SOCIETY
WASHINGTON, D.C., SEPTEMBER 27, 28, 29, 30, 1921
Headquarters, Meetings and Exhibits: Hotel Washington. Hotels: Hotel Washington and The New Ebbitt.

SIXTH ANNUAL MEETING THE AMERICAN RADIUM SOCIETY
BOSTON, JUNE 6 AND 7, 1921. HEADQUARTERS, HOTEL BRUNSWICK

WASHINGTON MEETING

The Twenty-second Annual Meeting of THE AMERICAN ROENTGEN RAY SOCIETY will be held in Washington, September 27, 28, 29 and 30, 1921. Headquarters, meetings and exhibits, will be at the Hotel Washington, Pennsylvania Avenue, opposite the Treasury.

Hotel accommodations for members and guests may be arranged at the Washington Hotel and The New Ebbitt. In making reservations state that you are attending the meeting of THE AMERICAN ROENTGEN RAY SOCIETY. Mr. A. Gumpert, Manager of the New Ebbitt, has agreed to see that all those attending the Convention are taken care of. Therefore anybody not getting what he wants should communicate direct with him.

The hotel rates are as follows:

Hotel Washington, every room having private bath with shower, tub and running ice water (European plan only):

	Per day
Single rooms	$5.00 to $7.00
Double rooms (double bed)	8.00
Double rooms (twin beds)	10.00 to 12.00

The New Ebbitt (European plan only):

	Per day
Single room without bath	$2.50
Single room with bath	4.00
Double room without bath, each person	$2.50
Double room with bath, each person,	3.50

Also a number of large suites, both with and without bath, which will comfortably accommodate upwards of four persons. On these suites they would make a rate of $3.00 per day each person, with bath, or $2.00 per day each person without bath.

For information regarding the program, those wishing to read papers or to show slides at the meeting should communicate direct with the President, Dr. A. C. Christie, 1621 Connecticut Avenue, N. W., Washington, D. C.

For information regarding commercial exhibits and other business matters connected with the meeting, address the Business Manager, Paul B. Hoeber, 67-69 East 59th Street, New York City.

It is hoped to arrange for special trains and cars from various sections. Details regarding this will be announced later.

PRELIMINARY ANNOUNCEMENTS

Dr. A. C. Christie, President of the Society, announces that plans for the program of the Annual Meeting of the Society next fall are now well under way. Dr. Réné Ledoux-Lebard will give the Caldwell Lecture on the subject of "Deep Roentgen Therapy." It is planned to give a much larger place on the program to papers on therapy than has hitherto been done. The plan is to hold the meeting for four days, giving the entire first day to papers on therapy and to have the papers on physics during the forenoon of the second day. This will

enable those who are interested only in therapy to leave about the middle of the second day, while those interested only in roentgen diagnosis would not feel it necessary to atend until the beginning of the second day. Those interested in both diagnosis and therapy would probably wish to be present the entire four days.

It is believed that this plan will make the meeting of interest to a much larger number of men. It is requested that those who have papers to present at the meeting communicate with the President of the Society at as early a date as possible.

A. C. CHRISTIE.

WESTERN SECTION

THE AMERICAN ROENTGEN RAY SOCIETY

The second annual meeting of the Western Section of The American Roentgen Ray Society will be held at Portland, Oregon, May 27th and 28th, 1921. The headquarters will be at the Portland Hotel, and the Chairman of the Local Committee on Arrangements is Dr. Roy A. Payne, Stevens Building.

Every facility will be provided for the demonstration of plates and slides. On Friday afternoon time will be taken for an automobile trip over the famous Highway, and the banquet will be held on Friday night, May 27th.

The National Society has been requested to send President Christie to the meeting, and it is hoped that he will be present. One day of the meeting will be occupied by the Western Section of The American Roentgen Ray Society, and the other day by the Pacific Coast Roentgen Ray Society. The following papers have already been promised for the Western Section program:

Super-radiation and Delayed Reactions; Albert Soiland, M.D., Los Angeles.

Postural Variations in Cecum and Colon and their Interpretation; Roy A. Payne, M.D., Portland, Oregon.

Fractured Vertebrae; William B. Bowman, M.D., Los Angeles.

Treatment of Leukemia; H. B. Thompson, M.D., Seattle.

Subject to be announced; Dr. Charles M. Ruggles, San Francisco.

Subject to be announced; Dr. Charles M. Richards, San Jose.

The Pacific Coast Society will have several papers of interest in their Section, and the meeting promises to be very successful.

W. WARNER WATKINS, Secretary.

Subscribers to THE AMERICAN JOURNAL OF ROENTGENOLOGY *visiting New York City, are invited to make the office of* THE JOURNAL (69 *East 59th Street, New York*) *their headquarters. Mail, packages or baggage may be addressed in our care. Hotel reservations will gladly be made for those advising us in advance; in this case, kindly notify us in detail as to requirements and prices. List of operations in New York hospitals on file in our office daily.*

BOOK REVIEWS

GRENZEN DES NORMALEN UND ANFAENGE DES PATHOLOGISCHEN IM ROENTGENBILDE. By Prof. Doctor Alban Köhler, Wiesbaden. Third Edition, revised and enlarged. xi + 415 pages. Illustrated. Published by Lucas Gräfe and Sillem, Hamburg.

It has been a distinct pleasure to review the third edition of Dr. Köhler's book which appeared in May, 1920.

This edition has been enlarged by nearly one third. As it was impossible for Dr. Köhler, during the period of the war, to have access to the medical literature of the world, the revision represents almost entirely the results of his own investigations and experience. There are 415 pages of text introduced by a general part of eleven pages. All sections of the edition have been more or less enlarged, important additions having been made to the general section and the sections dealing with the cardiovascular system, the osseous system and pneumatic cavities. Attention is given to the outlining of growing bone, to inconstant parts of the skeleton, islands in the compacta, general disturbances of growth and to a great number of minor conditions of the skeleton. These are thoroughly described in 238 pages. Sixty pages are devoted to the thorax and 105 to the abdomen. Concerning the gastro-intestinal tract there has been no change made beyond that contained in the second edition. There is a complete index and an extensive bibliography.

The author, in his preface to this edition, calls attention to the illustrations which are tracings of the original roentgenograms, exact to the millimeter, and mechanically reduced in the Academy of Arts. These tracings are excellent in their simplicity without undue elaboration and consequently reveal at a glance the normal condition or lesion they are intended to illustrate.

The object of Dr. Köhler's book is concisely summarized in the title. Its value lies mainly in its descriptions of early pathologic changes and its demonstrations of the wide variations which may exist within normal limits and which are a constant source of error in the interpretation of roentgenograms. Typical lesions have been described and pictured often enough; the great difficulty lies in making accurate diagnoses of early pathologic changes, in view of these wide limits of normal variation.

This excellent discussion of normal and early pathologic processes should be carefully studied by every physician contemplating the study of roentgenology, and even the expert would profit by carefully reading this work, for it presents the very foundation upon which interpretation rests.

R. D. CARMAN.